

**UNCLASSIFIED**

**AD\_464228**

**DEFENSE DOCUMENTATION CENTER**

**FOR**

**SCIENTIFIC AND TECHNICAL INFORMATION**

**CAMERON STATION ALEXANDRIA, VIRGINIA**



**UNCLASSIFIED**

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

AVAILABLE COPY WILL NOT PERMIT  
FULLY LEGIBLE REPRODUCTION.  
REPRODUCTION WILL BE MADE IF  
REQUESTED BY USERS OF DDC.



CATALOGED BY: DDC

AS AD NO. 464228

464228

DEPARTMENT OF PSYCHOLOGY

KANSAS STATE UNIVERSITY  
MANHATTAN

FEB 27 1965  
JUN 3 1965  
JUL 1 1965  
TUES

**Best  
Available  
Copy**

**Technical Reports 25-28**

**The Evolution of Perceptual  
Frames of Reference<sup>1</sup>**

**These reports describe work under contract Nonr-3634(01)  
between Kansas State University and the Physiological  
Psychology Branch, Office of Naval Research.**

**The principal investigator is William Bevan.**

**Reproduction in whole or in part is permitted for any  
purpose of the United States Government.**

**Department of Psychology**

**May, 1965**

**Technical Report No. 25**

**Response Latency as a Function of the  
Temporal Pattern of Stimulation<sup>1</sup>**

**Donald Hardesty and William Bevan  
Kansas State University**

**1. This report describes an experiment performed under contract Nonr-3634(01) between Kansas State University and the Physiological Psychology Branch, Office of Naval Research. It is part of a project entitled "The Evolution of Perceptual Frames of Reference."**

**This paper has been accepted for publication in the Psychological Record.**

**Reproduction in whole or in part is permitted for any purpose of the United States Government.**

**May, 1965**

## **Response Latency as a Function of the Temporal Pattern of Stimulation<sup>1</sup>**

**Donald Hardesty and William Bevan  
Kansas State University**

This paper reports three simple experiments on vigilance that were motivated by an interest in the potential of the conceptual approach of Adaptation Level Theory for explaining vigilance phenomena. Theories of vigilance to date have been broadly-drawn thematic statements, each oriented chiefly about a major vigilance problem. For example, Mackworth's Conditioning Theory (1950) is directed toward explaining vigilance decrement and Deese's Expectancy Theory (1955) toward accounting for variations in detection efficiency with changes in signal rate. Adaptation Level Theory offers the promise of quantitatively accommodating a variety of vigilance data.

The first two experiments test predictions shared by Expectancy Theory, Uncertainty Theory and AL Theory and clarify some earlier data of Baker (1959b). The third attempts to differentiate in quantitative terms between these several theories.

Response latency rather than relative frequency of detection is used throughout as the measure of vigilance level for two reasons: it is a more sensitive response measure than frequency of detection and, as a continuous variable, it is suited to the quantitative operations of AL Theory. These experiments differ from the usual reaction-time experiments in that no premonitory cue was employed, signals were weak in intensity, and, in the second and third experiments, the interstimulus interval was variable in duration.

### **Experiment I**

In an early systematic treatment of vigilance, Deese (1955) identified vigilance level with strength of expectation and, in turn, hypothesized this latter to be a function of the course of stimulus events within the task prior to any test trial. From this he extrapolated to the position that detection for a given signal is related to the average of all prior intersignal intervals. For signals following an interval shorter than average, expectancy, and thus vigilance, is expected to be low. As duration increases, vigilance increases. As it exceeds the average, vigilance continues to increase. At the time of writing no data were available to clearly support these views.

Baker (1959a) extended and modified Deese's view. Specifically, he proposed that expectancy, and thus vigilance, increased as interval duration approached average duration and then decreased with longer intervals. To test this prediction, he repeated an experiment of Mowrer (1940) in which a series of 20 signals were presented at 10-second intervals and immediately followed by a test signal after, on separate trials, 2, 5, 20, 25, or 30 seconds. For the two- and five-second test intervals, response latency was clearly longer than for the adaptation series. However, response latencies for the three longer intervals were not reliably greater than for the ten-second standard.

The Deese and Baker formulations are explicitly probabilistic and the extension of the assumption of perceived statistical structure to the use of the average as a reference value for response would appear in large part to be intuitive. Not so for AL Theory. It begins with the assumption that judgmental norms derive from the continuous integration of stimulus magnitudes over time. The intensive character of the particular judgment in turn is represented by the deviation, on the single trial, of stimulus magnitude from the adaptation level, irrespective of direction. This latter value is best approximated by a weighted mean of the series. If it is assumed that intersignal-interval duration is analogous to stimulus magnitude, then adaptation level would predict that the decrement in response latency ( $\Delta RL$ ) would increase up to some limiting value as the difference between test interval and mean interval increased.

The present experiment is an elaboration of the Baker experiment with three different adaptation-series intervals (10, 20, 40, and 80 sec.). Independent groups were used for every combination of series and test intervals.

Subjects. One hundred fifty male students in introductory psychology divided randomly into the 15 groups just described, 10 Ss per group.

Apparatus and Procedure. Ss were tested individually. S and E sat on opposite sides of a table, separated from each other's view by a large, black wooden screen. On S's side a wooden apron extended from the screen to the edge of the table at an angle of about 30 degrees. The visual display consisted of a one-half in. circular aperture at the center of the screen, back-lit by a small signal lamp with amber filter. The rest of the apparatus consisted of a Standard electric timer reading to 1/100 sec. and two silent low-friction, three-way AH & H Quiet-Ease switches, one mounted on the apron in front of the subject, the other at E's station, all connected so that activation of E's switch simultaneously illuminated the light and started the clock, and activation of S's switch extinguished the light and stopped the clock. S was fitted with Willson Sound Barrier ear muffs equipped with high fidelity earphones through which S received 75 db white noise to occlude possible auditory distractions.

Upon S's entering the test room, he was asked to surrender his watch for the test period and then was seated

before the display. He was told that the experiment dealt with reaction time and instructed to keep his hand on the switch and turn off the light as soon as he saw it come on. Each S received 22 presentations of the light: one unrecorded practice trial, the adaptation series of 20 trials, and the final and critical test trial. The adaptation series followed the practice trial and in turn was followed by the test trial without note or interruption. All intervals between trials except the final one was of constant duration. The interval preceding this last trial was either the same as those preceding it or of some different duration.

Results. Initially, latencies for the adaptation series, averaged across series, were of the order of 350 to 400 msec. However, after 4 or 5 trials, they dropped to about 300 msec and showed little change on subsequent trials.

The solid lines in Figure 1 present decrement in response latency as a function of the duration of the test interval following each of the three adaptation series. It is readily apparent that the hypotheses of this experiment have been confirmed. In no case, when the test interval equaled the adaptation interval in duration, did  $\Delta RL$  differ from zero. [ $F_{adaptation \text{ vs. } test \text{ measures}}$  ( $1,29$ ) =  $0.72$ ,  $P < .05$ ]. Moreover, latencies clearly increased as the test interval deviated from the adaptation interval, and this increase appears to be independent of direction of difference per se [ $F_{between \text{ test} \text{ intervals}}$  ( $4,135$ ) =  $6.20$ ,  $P < .01$ ;  $F_{adaptation \times \text{test interval}}$  ( $9,135$ ) =  $5.64$ ,  $P < .01$ ]. The importance of the internal referent for response latency is seen in the differences in  $\Delta RL$  for a given test interval with different adaptation series. For example, in the case of the five-second test interval,  $\Delta RL$  is approximately 40, 60, and 120 msec. for the constant-interval condition with the 10, 20, and 40 msec. adaptation schedules, respectively. These data also make clear the basis for the asymmetry in the earlier Baker results.

## Experiment II

The data of Experiment I indicate the importance of an internal referent for response latency. They do not differentiate between the role of the most recent pretest interval, important to Conditioning Theory, and the temporal structure of the pretest adaptation series, important to Expectancy, Uncertainty, and AL Theory. However, this difficulty is readily remedied by substituting a variable-interval adaptation series for the constant-interval series previously used. Baker has done this already (1959b). In addition to the constant-interval 10-sec. adaptation series referred to above, he used a two-min. constant-interval series and two variable interval series with average interval durations of 10 sec. and two min., respectively. However, the results from these groups showed little variation in response latency from the 10 sec. constant interval group and thus failed to confirm

expectation. The present Experiment II repeated Experiment I with three variable-interval series replacing the three constant-interval series. The average intervals were accordingly 10, 20, and 40 sec. in duration. The frequency distributions of durations were designed to be symmetrical about the average with 40% of the durations at the average, 40% at a value 30% greater or less than the average, and 20% at a value 50% greater or less than the average. A two-fold prediction was made: (a) A RL would approximate zero when test-interval duration equaled the average interval duration of the adaptation series and would increase as ARL deviated from this value; and (b) the results of Experiment II would not differ significantly from those of Experiment I.

Subjects. One hundred fifty male students in introductory psychology, different from those of Experiment I, divided at random into fifteen groups of equal size.

Apparatus and Procedure. Experiment II was in all aspects the same as Experiment I except that the constant-interval series were replaced by the following schedules. For the 10-sec. group: in random order, two 5-sec., four 7-sec., eight 10-sec., four 13-sec., and two 15-sec. intervals. For the 20-sec. group: two 10-sec., four 14-sec., eight 20-sec., four 26-sec., and two 30-sec. intervals. And for the 40-sec. group: two 20-sec., four 28-sec., eight 40-sec., four 52-sec., and two 60-sec. intervals.

Results. The results of Experiment II are represented by the dotted lines of Figure I. The curves are again V-shaped and the nadirs do not differ significantly from the average of the adaptation series [Fadaptation vs. test measures (1,29) = 0.23,  $P > .05$ ]. Furthermore, in no instance do the values of each dotted curve differ from those of the comparable solid curve of Experiment I [10-sec. groups: FI vs. II groups (1,90) = 1.86,  $P > .05$ ; Fgroups X test intervals (4,90) = 1.37,  $P > .05$ . 20-sec. groups: FI vs. II groups (1,90) = 2.02,  $P > .05$ . Fgroups X test intervals (4,90) = 0.21,  $P > .05$ . 40-sec. groups: FI vs. II groups (1,90) = 3.15,  $P > .05$ ; Fgroups X test intervals (1,90) = 1.46,  $P > .05$ ].

The two-fold prediction of Experiment II thus is confirmed in both aspects and it would appear that response latency reflects the subject's ability to assess the statistical structure of the adaptation series. At the same time, one may expect that if the range of intervals used is increased, some limit will be reached beyond which the subject will be unable to assess the structure of the series and this will reflect itself in his vigilance behavior. Adaptation Level Theory is assumed to apply below this limit, for it makes no formal provision for differences in the clarity of the subject's impression of statistical structure and the relationship of this variable to variability and other properties of response.

### Experiment III

Both Deese (1955) and Baker (1959a), in their initial formulations of Expectancy Theory, have identified the adaptation-series mean as the internal referent. Yet there is nothing explicit in their formulations which justified the selection of the mean over some other measure of central tendency. Indeed, the idiom of the previous literature has been unclear. Discussions have included references to continuous averaging on the one hand, and to the perceived structure of sequences of events on the other. Jenkins (1958), for example, makes reference to the importance of the mean or prevailing rate of signal presentation for signal detection. Given a random series of variable intervals, several alternative behavioral strategies are equally plausible. Both the mode, as the most frequently occurring value, and the midrange as the value half way between the extremes, are reasonable choices as subjective standards for the minimization of error. In contrast, because it is based on a pooling model, Adaptation Level Theory is inevitably tied to the mean as the best approximation of the internal standard. Of course, since a symmetrical distribution of intervals was used in the above and similar experiments, the mean, mode, and midrange are all the same value and it is impossible to identify the nature of the averaging process from the resulting data. Accordingly, Experiment III employed an adaptation series in which mean, mode, and midrange were distinctly different values. The design involved three independent groups, with a common adaptation series but with test intervals that were either the mean, mode, or midrange of the pretest adaptation intervals. Based on the assumption of pooling, it is predicted that ARL for the group receiving the test signal after an interval of mean duration will not differ significantly from zero. Since, in the adaptation series used, the mode and midrange are equally different in magnitude from the mean, it is predicted that response latencies for the groups associated with these values will be longer on the test trial than on the average during the adaptation series and that their ARL's will be essentially equal in magnitude.

Subjects. Sixty female introductory psychology students served as subjects. They were divided into three equal-sized groups.

Design. All groups received the same adaptation series. It consisted of 20 variable-interval trials: 10 trials after 10 sec., 4 trials after 15 sec., and 2 trials after 20, 25, and 30 seconds. The order of presentation was random. The mode, mean, and midrange of this distribution are distinctly different values: 10, 15.5, and 20 sec., respectively. One group received the test signal after the mode, one after an interval of approximately mean duration (15 sec.) and one after the midrange.

Results. Figure 2 summarizes the data of this experiment.

The mean-interval group clearly displayed the most efficient test behavior; ARL appeared on the average to be slightly negative, indicating that response latency on the test trial was slightly shorter than during the adaptation series. However, the first prediction was in fact confirmed, for the 1<sup>st</sup> confidence interval about the mean ARL value of -6.1 seconds included zero. This mean value is significantly shorter than the other two test values [ $F_{mean}$  vs. mode, midrange (1,57) = 17.3,  $P < .01$ ]. These latter (mode = 20.2 sec. and midrange = 21.0 sec.) in turn do not differ significantly from each other [ $F_{mode}$  vs. midrange (1,57) = .01,  $P > .05$ ]. Thus the second prediction also is confirmed.

These results receive broad support from Baker's report (1962) that the probability of signal detection is maximal at the mean. Baker obtained the U-shaped performance curve, but the range of intervals with maximum detectability was so broad as to make his conclusion about the mean equivocal. In addition to the present results, convincing evidence that the subject is in fact pooling and deriving means rather than simply constructing frequency distributions is found in two studies each of which employed rectangular distributions. An examination of Klemmer's (1956) data and those of Woodrow (1914) reveals that the shortest reaction times were associated with the mean interstimulus interval.

The three experiments presented in this paper indicate that the temporal pattern of immediately preceding signals is a significant determinant of response latency following a simple visual signal. When, for example, in Experiment I the 10-sec. interval preceding the test signal was itself preceded by a series of signals at 10-sec. intervals, response latency was about 280 msec. However, when the adaptation stimuli were spaced at 20-sec. intervals, response latency following a 10-sec. test interval was approximately 310 msec. In further contrast, when the adaptation stimuli were spaced at 40-sec. intervals, response latency following the 10-sec. test interval was about 400-msec. Similarly, response latencies associated with the 40-sec. test interval following adaptation series spaced at 10, 20, and 40sec. were respectively 335, 320, and 280 msec. Experiment II indicates that the subject's best estimate of the duration of test interval is based on an average of the immediately preceding series interval and Experiment III in turn identifies the mean as the best approximation of this average.

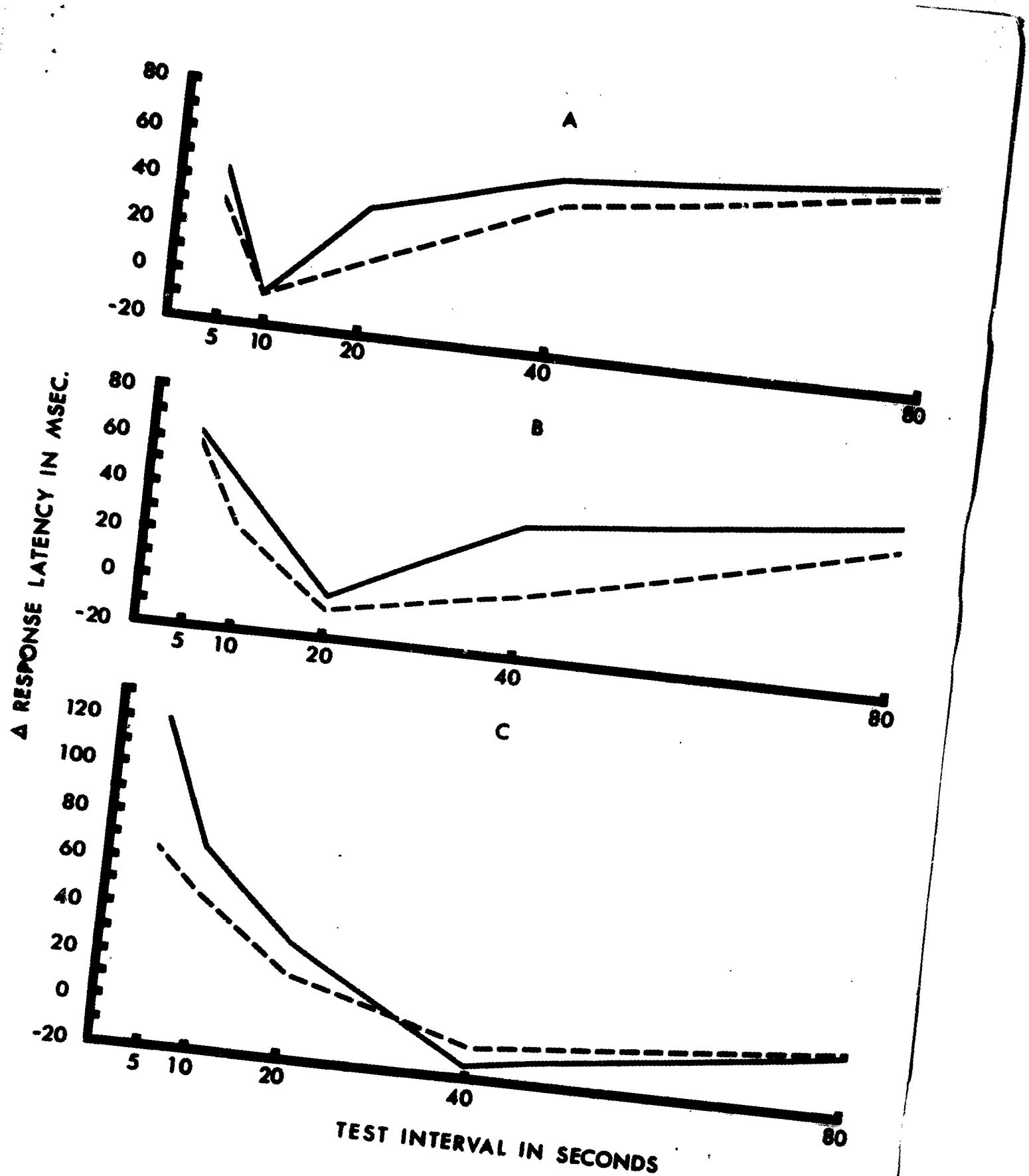
Thus, it would appear that a mechanism similar to the adaptation level in sensory judgment appears to operate in determining response latencies in the simple vigilance situation.

REFERENCES

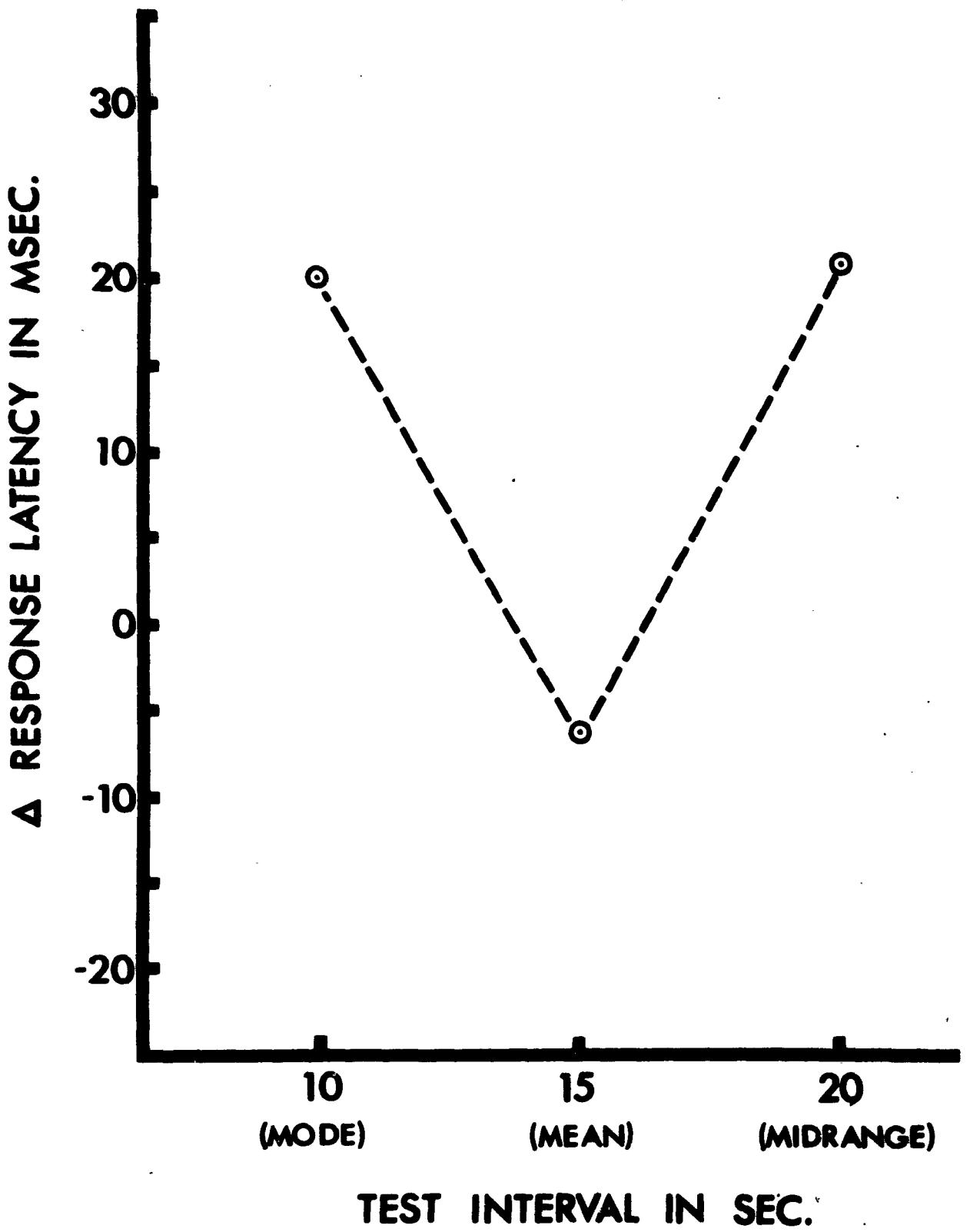
- Baker, C.H. Towards a theory of vigilance, Canad. J. Psychol., 1959a, 13, 35-42.
- Baker, C.H. Three minor studies of vigilance. Def. Res. Bs. of Canad., DRML Rpt., No. 234-2, 1959b.
- Baker, C.H. Probability of signal detection in a vigilance task. Science, 1962, 136, 46-47.
- Deese, J. Some problems in the theory of vigilance. Psychol. Rev., 1955, 62, 359-368.
- Jenkins, H.M. The effect of signal-rate on performance in visual monitoring. Amer. J. Psychol., 1958, 71, 647-661.
- Klemmer, E.T. Time uncertainty in simple reaction time. J. exp. Psychol., 1956, 51, 179-184.
- Mackworth, N.H. Researches on the measurement of human performance. Med. Res. Council Special Rpt. No. 268, London: H.M. Stationery Office, 1950.
- Mowrer, O.H. Preparatory set: Some methods of measurement. Psychol. Monogr., 1940, 52, Whole No. 233.
- Woodrow, H. The measurement of attention. Psychol. Monogr., 1914, 17, Whole No. 76.

1. This work was performed under contract Nonr-3634(01) between the Physiological Psychology Branch, Office of Naval Research, and Kansas State University. D.H. is now staff psychologist with the Standard Oil Company (Ohio) at Cleveland, Ohio.

Fig. 1. Response decrement on the test trial plotted for three different adaptation series and five test intervals. The solid lines are for constant interval adaptation series; the dotted lines are for variable interval adaptation series. A presents results for the 10-sec. adaptation series, B for the 20-sec. adaptation series, and C for the 40-sec. adaptation series.



**Fig. 2. Response decrement on the test trial when the test interval was equivalent to the mode, mean, or median of the adaptation series.**



Technical Report No. 26

Response Latency with Constant and Variable  
Interval Schedules<sup>1</sup>

William Bevan, Donald L. Hardesty, and Lloyd L. Avant  
Kansas State University

1. This report describes an experiment performed under contract Nonr-3634(01) between Kansas State University and the Physiological Psychology Branch, Office of Naval Research. It is part of a project entitled "The Evolution of Perceptual Frames of Reference."

This paper appeared in Perceptual and Motor Skills, 1965, 20, 969-972.

Reproduction in whole or in part is permitted for any purpose of the United States Government.

May, 1965

**Response Latency with Constant  
and Variable Interval Schedules<sup>1</sup>**

William Bevan, Donald L. Hardesty  
and Lloyd L. Avant

Kansas State University

The present study joins a literature of about a dozen papers, dating from Woodrow's 1914 monograph, concerned with the regularity of the temporal program of stimuli and its relation to response efficiency. The largest number of these experiments involve varying the length of the foreperiod in the traditional reaction time paradigm, with the maximum interval used to date being 15 sec. (Botwinick and Brinley, 1962). The common finding has been that reaction times are shorter for the constant foreperiod schedule. Botwinick and Brinley, however, report this advantage to be reduced as duration of foreperiod increases and to be lost with fore-periods of 15 sec.

Meanwhile, recognition of reaction time as a sensitive measure of behavioral efficiency has led to its exploitation in the study of vigilance. Here procedure varies from the reaction-time experiment in that the premonitory cue is omitted and the interstimulus interval replaces the foreperiod, the intervals are considerably longer in duration, and primary concern is for response efficiency over a series of trials rather than on a single trial. Studies of response latency as a function of the regularity of the schedule of presentation have been unsystematic and the results, taken in total, are unclear. McCormack and Prysieznik (1961) confirmed with a 60-sec. interval the relationship between constant and variable foreperiods in the reaction-time studies. Adams and Boulter (1964) report similar results for a 195 sec. interval, but Boulter and Adams (1963) failed to demonstrate a significant difference for a 220 sec. interval.

The purpose of the present experiment was to examine the relationship of response latency to regularity over a wide range of interval durations: on the one hand, overlapping the range of the reaction-time experiments and, on the other, extending beyond the durations of vigilance studies dealing with this problem. Accordingly, independent groups were tested with intervals of 10, 20, 40, 80, 160, and

320 sec. respectively. Half received the signals on a constant-interval schedule and half on a variable-interval schedule such that 40% of the intervals were at the average, 40% at values 30% greater or less than the average, and 20% at values 50% greater or less than the average.

#### Experimental Situation

Subjects. Three hundred eighty male students in Introductory Psychology served as subjects. Six groups, those for the 10, 20, and 40 sec. intervals, contained 50 subjects each. These subjects were participants in another experiment (Hardesty and Bevan, 1965), and the present data for these groups were collected incidental to that study. The remaining groups were added to extend the range of intervals covered. The 80 sec. groups consisted of 20 subjects each, and the 160 and 320 sec. groups of 10 subjects each.

Apparatus. The experimental task involved the detection of the onset of a small amber light. The visual display consisted of a large black screen which separated S and E, with a one-half in. circular aperture at its center, backed by an amber filter and a small signal lamp. A wooden apron mounted to the subject's side of the screen at an angle of about 30 degrees contained S's response switch. A second switch was mounted on E's side of the screen. These were both low-friction silent devices. Activation of E's switch simultaneously illuminated the signal lamp and started a Standard Electric Clock, calibrated to read to 1/100 sec.; depression of S's switch extinguished the light and stopped the clock. White noise fed through head phones was used to occlude possible auditory distractions.

Procedure. When seated before the display, S was informed that he was participating in a reaction-time experiment and told to keep his hand on the switch and turn off the light as soon as he saw it come on. Each S received a sequence of 21 trials, 1 unrecorded practice trial, and 20 data-yielding trials. Subjects in the constant-interval groups received the signals at one of the durations indicated above. The 10 sec. variable-interval schedule consisted of the following intervals, presented in random order: two 5-sec., four 7-sec., eight 10-sec., four 13-sec., and two 15-sec. intervals. For the 20, 40, 80, 160, and 320 sec. variable schedules, the intervals of the 10-sec. schedule were multiplied by a factor of 2, 4, 8, 16, or 32, respectively. The order of presentation remained the same.

#### RESULTS

Figure 1 presents the data for each group averaged across 20 trials. The solid curve represents the results for the constant-interval groups; the dotted line the performance of the variable-interval groups. Inspection of the results for individual trials revealed that response latency stabilized in the fourth or fifth trial and remained essentially

constant throughout the rest of the test sequence. It is interesting to note that response latencies for the shorter intervals are of the same order of magnitude as the reaction-time data of earlier studies (cf. eg. Klemmer, 1956; Karlin, 1959), while those for the longer-intervals fell well below the 800-1000 msec. responses reported by Adams and Boulter (1964) for a similar vigilance task. The two curves are negatively accelerated and constitute a clear-cut extrapolation of the relationship, already apparent in the reaction-time data (cf. Karlin, 1959; Botwinick and Brinley, 1962), that response time increases as the duration of the interval increases [ $F_{interval} = (5,368) = 101.38, P < .01$ ]. For the present experimental situation it would appear to be maximal at slightly less than half a second.

The data of this experiment are also consistent with the results of the majority of the reaction-time studies on the variable foreperiod. With only one exception, the data for the 40 sec. groups, response latencies are consistently shorter for the constant interval condition [ $F_{interval \times conditions} = (1,368) = 29.10, P < .01$ ], and in the light of the overall findings, we are inclined to identify the 40-sec. variable interval mean as a vagary of sampling. Furthermore, as the average interval increases to 160 msec., the magnitude of the difference between conditions increases [ $F_{constant \times variable} (5,368) = 3.55, P < .01$ ].

The relationship between response latency and the regularity of the interval schedule appears to be independent of the shape of the frequency distribution of interval durations, for it obtains for the symmetrical distribution of the present experiment and also for rectangular distributions of the Karlin (1959), Botwinick and Brinley (1962), McCormack and Prysiakniuk (1961) and Adams and Boulter (1964) studies. This observation is of potential significance for the identification of the mechanism underlying response efficiency in this setting. Klemmer (1956, 1957), and later Garner (1962, Ch. 2), has discussed the variable foreperiod data in terms of time uncertainty. Similarly, the Deese (1955) and Baker (1959) theories of vigilance are based on the assumption that the subject assesses the statistical structure of the stimulus series and selects the most probable interval and thus anticipates the signal. But the correctness of this view cannot be established by the two-stage experiment that compares maximum certainty with maximum or some other degree of uncertainty. If it is assumed that the relationship between response latency and time uncertainty is positive, than a multiple-stage experiment should report the shortest latency for the constant interval condition, the longest for the rectangular distribution, and immediate values for groups in which the individual interval durations have unequal frequencies of occurrence. The experiments on time uncertainty to date have identified uncertainty with the duration of the individual interval or with the range of durations. They have employed rectangular distributions or have confounded range and the

frequency of the interval durations and thus their results are not unequivocal (Klemmer, 1956; Boulter and Adams, 1963). At any rate, they do not constitute a proper test of the hypothesis just proposed.

REFERENCES

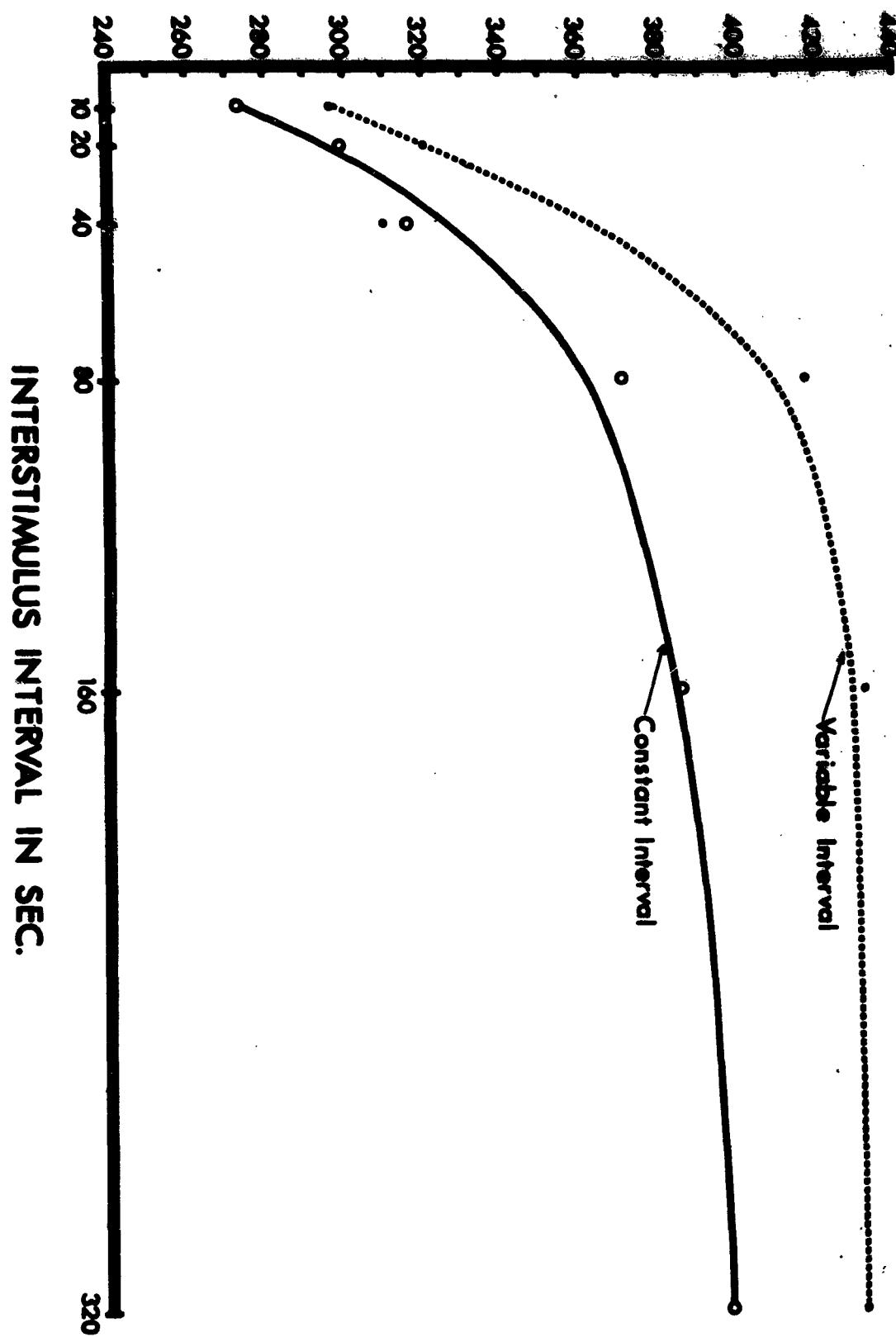
- Adams, J. A. and Boulter, L. R. Spatial and temporal uncertainty as determinants of vigilance behavior. J. exp. Psychol., 1964, 67, 127-131.
- Baker, C. H. Towards a theory of vigilance. Canad. J. Psychol., 1959, 13, 35-42.
- Botwinick, F. and Brinley, J. F. An analysis of set in relation to reaction time. J. exp. Psychol., 1962, 63, 568-574.
- Boulter, L. R. and Adams, J. A. Vigilance decrement, the expectancy hypothesis and intersignal interval. Canad. J. Psychol., 1963, 17, 201-209.
- Deese, J. Some problems in the theory of vigilance. Psychol. Rev., 1950, 62, 359-368.
- Garner, W. R. Uncertainty and structure as psychological concepts. New York: Wiley, 1962.
- Hardesty, D. and Bevan, W. Response latency as a function of the temporal pattern of stimulation. Unpubl. MS. 1965.
- Karlin, L. Reaction time as a function of foreperiod duration and variability. J. exp. Psychol., 1959, 58, 185-191.
- Klemmer, E. T. Time uncertainty in simple reaction time. J. exp. Psychol., 1956, 51, 179-184.
- Klemmer, E. T. Simple reaction time as a function of time uncertainty. J. exp. Psychol., 1957, 54, 195-200.
- McCormack, P. D. and Prysiazniuk, A. W. Reaction-time and regularity of inter-stimulus interval. Percept. mot. Skills, 1961, 13, 15-18.
- Woodrow, H. The measurement of attention. Psychol. Monogr., 1914, whole No. 76.

1. Supported by contract Nonr-3634 (01) between Kansas State University and the Physiological Psychology Branch, Office of Naval Research. Donald L. Hardesty is now staff psychologist with the Standard Oil Company of Ohio, Cleveland, Ohio.

**Legend for Figure 1.**

Response latency as a function of the duration of the interstimulus interval and the regularity of the stimulus schedule. The solid line connects means of groups receiving a constant-interval schedule; the dotted line connects means of variable-interval groups.

### MEAN RESPONSE LATENCY IN msec.



**Technical Report No. 27**

**A Study of Inflection Points in the Locus of  
Adaptation Levels as a Function of Anchor Stimuli<sup>1</sup>**

**Harry Nelson and Henry G. Masters**

**Kansas State University**

1. This report describes an experiment performed under contract Nonr-3634(01) between Kansas State University and the Physiological Psychology Branch, Office of Naval Research. It is part of a project entitled "The Evolution of Perceptual Frames of Reference."

**This paper has been accepted for publication in the American Journal of Psychology.**

**Reproduction in whole or in part is permitted for any purpose of the United States Government.**

**May, 1965.**

A Study of Inflection Points in the Locus of  
Adaptation Levels as a Function of Anchor Stimuli

Harry Nelson and Henry G. Masters

Kansas State University

According to the weighted log mean definition of the adaptation level (AL) we might expect AL to increase monotonically with increase in intensity of anchors above series stimuli and to decrease monotonically with decrease in intensity of anchors below series stimuli in accordance with Equation 1:

$$A = k(\bar{S}^{p q r}) \quad (1)$$

where A is the adaptation level, k is a constant,  $\bar{S}$  is the log mean of the series stimuli, R refers to residual stimuli, and p, q, and r are weighting factors, the sum of which is taken to be 1.0. Within limits this deduction is true as shown by the fact that even subliminal anchors have been found to raise judgments of intensity (lower AL) of electric shock by Black and Bevan<sup>1</sup>, of loudness by Bevan and Pritchard<sup>2</sup>, and of visual size by Boardman and Goldstone<sup>3</sup>. Similarly, at the upper end of the intensity scale it has been found that anchors two to four times the top series stimulus lower judgments of lifted weights, hence, raise AL as reported by Nelson<sup>4</sup> and Bevan and Darby<sup>5</sup>. From Equation 1, however, it is clear that if there is no background or anchor stimulus, the term  $B^q$  reduces to 1.0 because a zero stimulus is weighted zero and  $0^q = 1.0$ . In this case, AL is determined wholly by the series stimuli if we assume no residual effects. Thus, AL is higher with zero (no) anchor than with anchor below the series stimuli. Anchors below series stimuli depress AL up to a certain point after which AL must reverse and approach series AL as the anchor approaches zero. This deduction was actually anticipated in an experiment by Pratt<sup>6</sup> who found that AL was lower when a 15 gm. stimulus was interpolated between a standard of 100 gm. and series weights of 92, 100, and 108 gm. than when no interpolated stimulus was used. Similarly, Nelson<sup>7</sup> found AL was lower with 5 gm. anchor than with 0.5 gm. anchor and series weights of 200, 250, 300, 350, and 400 gm. Inflection points in the locus of ALs below series stimuli should, therefore, be found experimentally.

Turning to the upper end of the stimulus continuum, we find from the logarithmic form of Equation 1:

$$\log A = \log k + p \log \bar{S} + q \log B + r \log R \quad (2)$$

that the influence of anchors (B) should level off with increasing intensity, but there is no a priori reason why there should be an inflection point in the locus of anchors above series stimuli. Without looking explicitly for a drop in AL with extreme anchors, Bevan and Darby<sup>8</sup> found some loss in effectiveness of an anchor of 1950 gm. as compared with anchor of 1231 gm. with series stimuli ranging from 220 to 340 gm. The value of AL with anchor of 1950 gm. was 329 gm. as compared with AL of 332 gm. with anchor of 1231 gm. which, if confirmed in further experimentation, points to an inflection point at the high end of the stimulus continuum.

The presence of inflection points in the locus of ALs at both the lower and higher ends of the stimulus continuum raises several basic questions which we shall seek to answer in this study. First, if effectiveness of anchors does not increase monotonically as anchors increase in heaviness, loudness, etc., is the weighted log mean definition of AL invalidated? Second, what is the significance of inflection points at the high end of the stimulus continuum? Third, can we expect inflection points in both the low and high ends of stimulus continua in all sense modalities? And fourth, are there any implications from the results of these data bearing on the problem of relevance of anchors or the extent to which stimuli (including anchor stimuli) pool to form level? We shall attempt to answer these questions after presenting the data of this experiment which are based on anchors varying over a range of 1200: 1 using lifted weights as the stimuli.

Subjects. Twelve college students from the Kansas State University summer session served as Ss. Their class rank ranged from sophomore to graduate student. One S was dropped after the first session for failure to follow instructions.

Apparatus. Five medicine bottles measuring 1 1/2" x 1 1/2" X 3 1/4" served as the series stimuli. Each bottle was filled with lead shot to make a series of 100, 150, 200, 250, and 300 gm. In addition to the series stimuli, there were 12 anchor weights. While the anchor stimuli varied in size, weight, and height, all had tops of equal size where they were grasped for lifting. A cardboard collar, which fitted just below the top of each container, prevented Ss from getting differential cues from differences in size of the anchors. The differences in height were controlled by placing each stimulus on a piece of sponge rubber of appropriate height so all weights were lifted from the same starting height. A black cardboard screen was in front of S at all times so that the stimuli were never visible. S lifted the weights by putting his hand under the screen. A 5" x 8" card was mounted on the black screen at eye level on which the judgment

categories were displayed throughout the testing session. The anchor weights were: 1.56, 3.12, 6.25, 12.5, 25, 50, 100, 200, 400, 800, 1600, and 2879 gm., forming a geometric series except for the last which had to be less than twice 1600 gm. because of the physical limitations in lifting in this experimental situation.

Procedure. Each S was tested on all anchors except the 100 gm. anchor. (The specific procedure for this anchor will be presented later.) Three test sessions were required, with four anchors presented in each session. The order of presentation for the different anchor weights was randomly determined. Within each test session a five-minute recess separated anchor series. The time between stimulus presentations was held approximately constant by a fixed rhythm of presentation. The specific test procedure for each S was as follows: with S standing in front of the screen E read these instructions: "This is an experiment in the judgment of lifted weights. You will be given a series of weights to judge in terms of the following scale: very very heavy; very heavy; heavy; medium heavy; medium; medium light; light; very light; very very light. If you wish to use more extreme categories such as extremely heavy and extremely light, you may do so. There is no right or wrong. We want you to report how the weights feel to you. Later you will be given other series of stimuli to judge that will be heavier or lighter than the present series. Are there any questions?" E then presented S two practice runs with only the five series stimuli. Then E presented five test runs, without anchor to obtain the series AL. The presentation of each stimulus in each run was randomized. After the five test runs S rested for five minutes and then E read these instructions: "In the following observations the stimulus you are to report on will follow another stimulus. Remember you are not judging the first stimulus; you are judging the second stimulus. Nor are you judging the second stimulus relative to the first. Please report how the second stimulus feels in just the same way as you did in the first series when you were given only one stimulus at a time. Use the same categories as you did before." Then E presented S with one practice run. The anchor always preceded the series stimuli and the same procedure with respect to practice test runs and rest periods was followed which was used in the determination of the series AL. The instructions were repeated at the beginning of each test session and before the presentation of the first anchor series. The second and third test sessions were conducted in exactly the same manner as the first test session. None of the Ss were informed of the details of the experiment after testing, and they were asked not to discuss the experiment with anyone else.

Due to an oversight on the part of E, the 100 gm. anchor was omitted in the first three test sessions. Therefore, E requested the original 11 subjects to return for one more test session to obtain data with the 100 gm. anchor. Of the original 11 subjects, six returned for this additional test

session. It was conducted exactly like the three test sessions before it. The data for this anchor are thus based on six instead of 11 Ss.

Results. Data from 11 Ss judging the five series stimuli five times, each in random order with each of 11 anchors, and from six of the 11 Ss judging with the 194 gm. anchor, as noted above, were averaged, and curves were fitted to each. ALs were computed for each of the anchor conditions, as well as the 'no anchor' condition, according to Helson's formula<sup>9</sup> as illustrated in worked examples by Helson and Himmelstein<sup>10</sup>. The locus of ALs for anchors ranging from zero (no anchor) to 2879 gm. is shown in Fig. 1. from which it appears that there are two inflection points: the first occurs with anchor of 25 gm. where AL is lowest, and the second at 1600 gm. where AL is highest. In the former case, judgments of the series stimulus were, on the average, highest, and in the latter case, they were lowest, since there is an inverse relationship between value of AL and judgments of weight or any other dimension of stimuli. As values of AL rise with decreasing anchors below 25 gm., judgments of the heaviness of series weights decrease; similarly, there is a reversal in judgments of series weights at the high end of the continuum, since AL with 2879 gm. anchor is lower than with 1600 gm. anchor.

Decreasing effectiveness of visual anchors with increase in size of anchor was found by Bevan and Pritchard<sup>10</sup> who found that when rectangles were very much larger than series stimuli they no longer functioned as anchors in judgments of shape, although their linear dimensions were in the same ratio as those of smaller rectangles that functioned as anchors.

Tests of the significance of differences between ALs were made by means of Sandler's A-test<sup>11</sup>, a modified t-test. As appears from Table 1, all anchors except 200 gm. anchor are significantly different from the no-anchor condition. Since the 200 gm. anchor is very close to the series AL of 194 gm., it would not be expected to exert significant effect on AL. Nor are anchors of 1.56, 3.12, 6.25, 12.5, 25.0, and 50.0 gm. at the low end and 1600 and 2879 gm. at the high end significantly different from each other. Anchors from 1.56 through 50.0 gm. also differ significantly from anchors 200 through 2879 gm.

We thus see that stimuli within the series which serve as anchors do not displace AL to a significant degree from the series AL or no anchor condition. On the other hand, the fact that ALs are higher with anchors on either side of AL with 25 gm. anchor is evidence for an inflection point at this value even though there is no statistically significant difference between this anchor and the lower anchors with the exception of the zero anchor (series AL). Similarly, at the high end of the continuum, 2879 gm. anchor is not significantly different from the next two highest anchors, 800 and 1600 gm, which argues for at least a levelling off, if not an inflection point, of anchor effects at the high end of the intensive continuum.

### Discussion

We are now in a position to answer some of the questions raised at the beginning of this report and to venture some hypotheses regarding the others.

The first question asked above is easiest to answer. Inflection points in the locus of ALs do not mean that the weighted log mean definition of AL is inadequate. They merely show that the weighting coefficients, p, q, and r, for series, anchor, and residual stimuli are not constant over the entire range of stimulus intensities. This result is not surprising in view of the fact that no psychophysical law has been found or is likely to be found with fixed parameters for the entire range of stimulus intensities. The fact that the weighting factors, p, q, and r, may vary within a given dimension, especially at the extremes of the stimulus continuum, does not invalidate the generality or power of the weighted log mean definition. On the contrary, this definition provides the simplest and most general way of determining the contributions of the various classes of stimuli entering into AL. Just as variation in size of the jnd over the stimulus continuum does not invalidate the concept of the jnd, so variation in the weighting coefficients for series, background, and residual stimuli does not invalidate either the concept of AL or the concept of differential pooling in the formation of ALs. Where the locus of ALs is fairly linear, we may expect values of p, q, and r to be fairly stable; where there are inflection points we would expect the values of these constants to change. Determination of inflection points can therefore furnish important information regarding the contributions of various stimuli to the formation of ALs and the nature of pooling processes.

The significance of inflection points in the locus of ALs must be sought in the nature of the sensory and response systems involved in judgment and in the specific conditions of experimentation. In the case of lifted weights, we have seen that if series AL with no anchor stimulus is higher than with very low anchors, there must be a loss of effectiveness in anchors below a certain point. The situation is different at the high end of the scale where there is certainly no further upward shift of AL with heavier anchors after 1600 gm. and where the drop in AL may indicate an inflection point, even though the difference between 1600 and 2879 gm. is not statistically different. It appears probable that as anchors become heavier and heavier vis-a-vis series stimuli different muscles and a different stance are employed in lifting the anchor stimuli with resultant changes in judgment. We know that perceived weight is influenced by the shape and volume (density) of the stimulus, by the way in which the stimulus is grasped and lifted, and by other subtle factors too numerous to mention. By the time the anchor weighs over six lbs. (2879 gm.) as compared with an average weight of less than one-half lb. (200 gm.) for the series stimuli it is not surprising that

the lifting situation is considerably different for the anchor and series stimuli. Here the inflection point in the locus of ALs tells us to look for changes in stimulus and response conditions. This argument applies also to the low end of the stimulus continuum.

The third question can be definitely answered in the negative: inflection points are not expected, for example, at the low end of the reflectance or luminance continuum in vision. Absence of light in background does not function as a zero stimulus because black is a positive quality psychologically and, as background is made darker and darker, stimuli increase in lightness. Thus if black velvet having about 1/10 the reflectance of black cardboard is used as a background, a white stimulus of 80% reflectance appears to glow, so great is the contrast effect under high illuminances. We would therefore not expect any decrease in effectiveness of background or anchor stimuli at the low end of the brightness continuum. Due to glare and blinding effects of very high luminances there may well be inflection points in ALs for visual acuity and other visual dimensions at the high end of the brightness continuum. It is therefore necessary, as stated above, to investigate locus of ALs in each sense modality to determine effects of anchor and other stimuli.

The last question can be easily answered in the affirmative, for changes in the weighting constants, p, q, and r, give information regarding changes in the effectiveness of stimuli in pooling to form levels. We may define relevance in terms of the degree to which stimuli affect ALs. If stimuli do not affect AL they do not change responses. We thus have a quantitative measure of relevance in the values of the weighting coefficients for series, anchor, and residual stimuli. Wherever there are inflection points in the locus of ALs, either as a function of anchors, series stimuli, or residual factors, there we can say changes occur in the relevance of the various classes of stimuli pooling to form ALs.

In this discussion we have considered inflection points in the locus of ALs only as a function of variation in magnitude of anchor stimuli because the series stimuli were kept constant. It is obvious that inflection points depend also upon series as well as anchor stimuli and indeed are a function of both. Series and anchor stimuli interact, and with a heavier set of series stimuli we would expect the inflection point at the low end of the continuum to appear earlier, i.e., with heavier anchor, than in this study due to the apparent lightening of anchors with a heavier set of series stimuli. It is more difficult to predict what would happen at the high end of the stimulus continuum with a heavier set of series stimuli, owing to the fact that several factors having different effects interact. Thus stimuli are less effective with increasing magnitude in accordance with the Weber-Fechner law, yet anchors above a heavier series would feel less heavy than with a lighter series and would therefore function as lighter anchors. Still other factors may be

operative at the high end of the continuum to further complicate the situation so far as predicting what will happen. This and other questions raised by the present study can only be answered by additional experiments. Good theories answer some questions and raise others. The problem of inflection points in the locus of ALs is important because stimulus continua are divided into at least three regions: the region of neutrality in the vicinity of AL and also into bipolar opposites, such as heavy and light, bright and dim, warm and cold, above and below AL. Exact determination of these regions has practical as well as theoretical importance, the possibilities of which should be fully explored in studies of inflection points in anchor and series effects.

#### Summary and Conclusions

Inflection points in the locus of ALs were studied as a function of anchors varying from 1.56 to 2879 gm. or 1200:1 with series stimuli of 100, 150, 200, 250, and 300 gm. Due to the fact that series AL is higher with zero anchor than with anchors below the series, including subliminal anchors, it was predicted from the weighted log mean definition that an inflection point would be found with anchors below the series stimuli, and this deduction was verified experimentally. With anchors above the series stimuli, we expect a levelling off in their effectiveness from the definition of AL, but a slight drop in AL with the heaviest anchor suggests that there may also be an inflection point at the high end of the stimulus continuum as well as at the low end. Since larger muscle groups and a new mode of lifting are required with extremely heavy weights, it is not surprising that extremely heavy stimuli are less effective as anchors. The presence of inflection points in the locus of ALs does not invalidate the weighted log mean definition; they merely point to the fact that the weighting coefficients for series, background (anchor), and residual stimuli are not constant over the whole stimulus range. In view of the lability and complexity of receptor, central and motor systems, it can hardly be expected that any psychophysical parameters will remain fixed over the entire range of stimulus magnitudes.

Inflection points at the low end of the stimulus continuum are expected only in the case of sense modalities having a true zero. Such is not the case, e.g., in vision, where absence of stimulation in a part of the field gives rise to positive qualities like black or complementary colors. Changes in the weighting coefficients of series and background stimuli make possible quantitative determination of degrees of relevance of stimuli in the pooling process under various conditions. A number of questions raised by the present study were answered and still others remain to be investigated within the framework of AL theory.

Footnotes

\*Received for publication May , 1965. This research was supported in part by the Office of Naval Research under contract Nonr-<sup>2</sup>f 34(01) with Kansas State University.

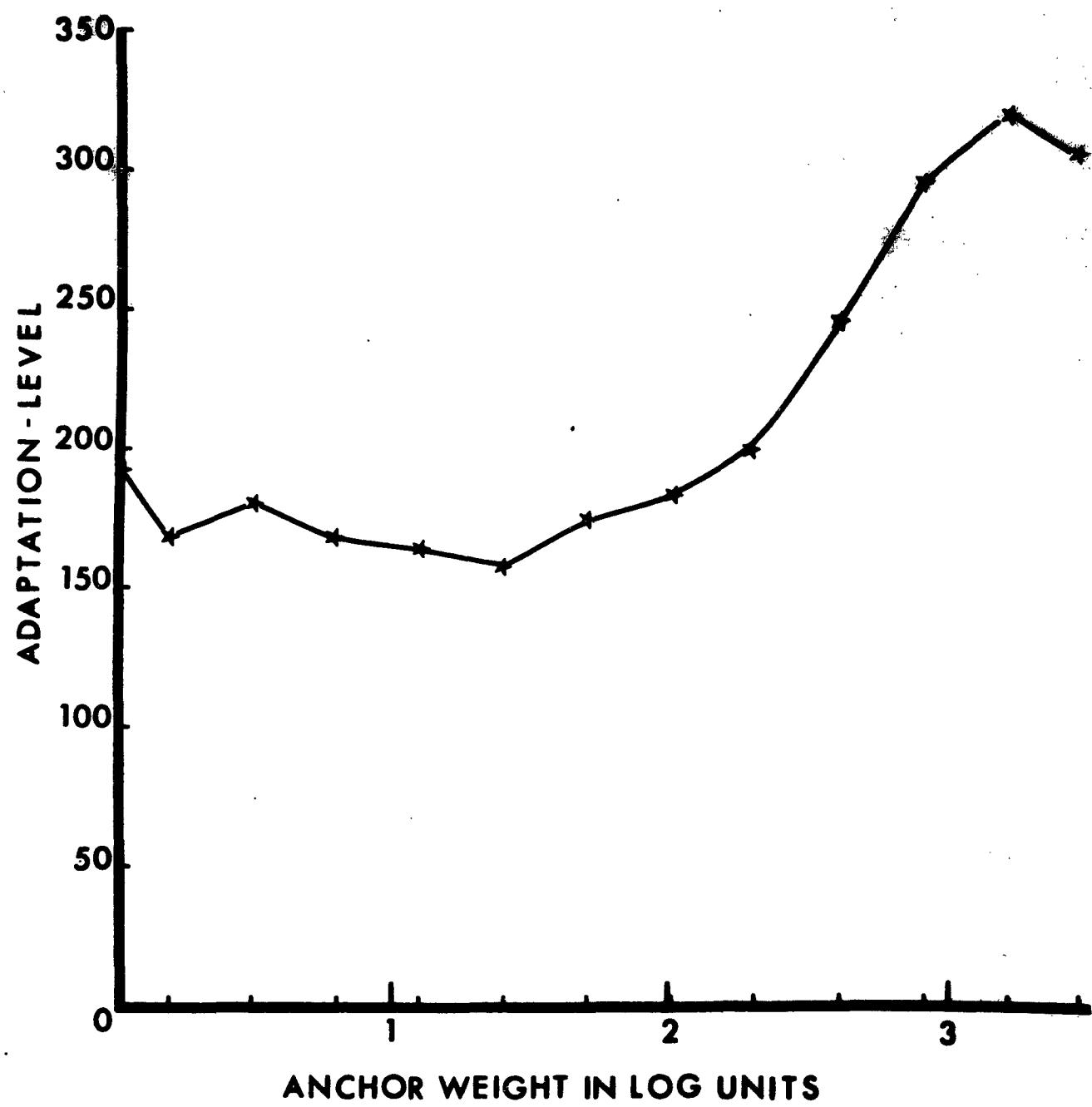
- 1 R.W. Black and William Bevan, the effect of subliminal shock upon judged intensity of weak shock, this Journal, 73 1960, 262-267.
- 2 William Bevan and Joan F. Pritchard, The effect of subliminal tones upon the judgment of loudness, J. exp. Psychol., 66, 1963, 23-29.
- 3 W.K. Boardman and Sanford Goldstone. Effects of subliminal anchors upon judgments of size, Percept. mot. Skills, 14, 1962, 475-482.
- 4 Harry Helson, Adaptation-Level Theory: An Experimental and Systematic Approach to Behavior, 1964, p. 135.
- 5 William Bevan and C.L. Darby, Patterns of experience and the constancy of an indifference point for perceived weight, this Journal, 68, 1955, 575-584,
- 6 C.C. Pratt, The time-order error in psychophysical judgments, this Journal, 45, 1933, 292-297.
- 7 Helson, op. cit., p. 142.
- 8 Bevan and Darby, op. cit., p. 580.
- 9 Helson, Adaptation level as a basis for a quantitative theory of frames of reference, Psychol. Rev., 55, 1948, 297-313.
- 10 Helson and P. Himmelstein, A short method for calculating the adaptation-level for absolute and comparative rating judgments, this Journal, 68, 1955, 631-637; also in Helson, op. cit., 1964, pp. 661-662.
- 11 Joseph Sandler, A test of the significance of the difference between the means of correlated measures, based on a simplification of Student's t, Brit. J. Psychol., 46, 1955, 225-227.

**Table 1**  
**Significance Levels of Differences Between ALs**  
**Based on Sandler's A-Test**  
**(values in parentheses are the anchors)**

AL (Anchor)	ALS and Anchors in Gm.					
194 (none)	171 (1.56)	181 (3.12)	171 (6.25)	165 (12.5)	159 (25.0)	176 (50.0)
171 (1.56)	.025	.05	.01	.025	.005	.01
181 (3.12)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
171 (6.25)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
165 (12.5)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
159 (25.0)				n.s.	.05	.005
176 150.0					.025	.005
184 (100)						.005
203 (200)						.005
247 (400)						.01
299 (800)						n.s.
323 (1600)						n.s.

**LEGEND FOR FIGURE 1**

**Fig. 1. Adaptation Level as a Function of Anchor Stimuli**



Technical Report No. 28

Perception<sup>1</sup>

Harry Helson

Kansas State University

1. This report describes an experiment performed under contract Nonr-3634(01) between Kansas State University and the Physiological Psychology Branch, Office of Naval Research. It is part of a project entitled "The Evolution of Perceptual Frames of Reference."

This paper in Helson, H. and Bevan W. (Eds). Theories and Data in Psychology. Princeton, New Jersey, D. Van Nostrand, in press.

Reproduction in whole or in part is permitted for any purpose of the United States Government.

May 1965

## PERCEPTION

Harry Nelson

Kansas State University

Since the time of Locke (1690) it has been believed that perception has a double aspect in which deliverances of the senses (sensations, dimensions, attributes) combine with central components (images, past experiences, cognitions) to yield percepts giving information about the properties and relations of objects. Perception has thus been regarded as having both outer and inner sources, the former responsible for our knowledge of the external world, the latter for individual differences in reactions to objects. Stemming directly from Locke is the notion that the organism (or mind, as he put it) is passive in its reception of sensory data, perceiving whatever comes to it. Sensory qualities are simple and irreducible; some, like colors, sounds, odors, tastes, and 'solidity' come through one sense only, and others, like space, extension, figure, rest, and motion come through two or more senses. According to Locke the qualities that resemble objects in the external world, solidity, extension, figure, and mobility are mediated by more than one sense and are called 'primary qualities' while the others have no reality, their qualities arising merely from the "powers (of objects) to produce various sensations in us." The latter are called 'secondary qualities' of which color, sound, and taste are examples. Although the mind at birth is a tabula rasa, it does have the power of compounding passively received simple ideas. The four types of active, compounding operations are distinction, comparison, abstraction, and combination.

Locke began with the intention of showing that all knowledge is derived from experience, or the simple deliverances of the senses, but he wound up with complicated compounding mechanisms requiring a number of mental activities to account for "knowledge" and "understanding". Locke's theories of mind and perception were the progenitors of later atomistic accounts given by James Mill and others. Complex ideas, according to Locke, merely combine simple ideas, e.g., substance + hardness + weight + ductility + fusability = idea of lead! Pure empiricism is usually found linked with genetic-atomistic approaches to problems and the reductio ad absurdum of such approaches is found in Locke's derivation of the meaning . . .

of infinity which supposedly is built up by thinking of something large, then something larger, then something still larger and larger, until finally one arrives at the notion of infinity!

While Lockian empiricism furnished a partial antidote to 17th and 18th Century rationalism which postulated innate ethical, religious, and mathematical truths, it did lead to Berkeley's subjective idealism wherein the external world was reduced to complexes of ideas having order only because of "divine intelligence". Carrying the radical empiricist argument to its logical conclusion led finally to Hume's uncaused "impressions" or "self-bundle of perceptions in movement" which Huxley characterized as follows:

For any demonstration that can be given to the contrary effect, the 'collection' of presentations which makes up our consciousness [according to Hume] may be an orderly phantasmagoria generated by the Ego, unfolding its successive scenes on the background of the abyss of nothingness; as a firework which is but cunningly arranged combustibles, grows from a spark into a coruscation, and from a coruscation into figures, and words, and cascades of devouring fire, and then vanishes into the darkness of the night (Huxley, 1901).

Neither the British empiricists, the British associationists, nor the pre-Gestalt psychologists who leaned heavily on Lockian principles, were able to give a satisfactory account of the meaning, order, and patterning found in perceptual processes. The doctrine of compounding which at first sight seems to offer the most economical conceptual frame of reference for handling the complicated facts of sensation, perception and mental life in general proves to be the least economical in the long run.

In contrast with the gross analyses of the philosophers and their psychological successors, the associationists, stands the analytical, introspective school founded by Wundt in Germany. Talk of objects on the one hand and ideas, impressions, and their associations on the other, was replaced in dealing with perceptual problems by careful correlations between controlled stimulation and, where possible, specific endorgans, and sensory processes. While Bishop Berkeley recognized the problem of perceiving depth and distance from flat retinal images and Bain stressed the importance of the muscle-sense of kinesthesia (Cf. Boring, 1942), it was the structural school of psychology which made the detailed study of stimulus-sensory correlations the main program of an experimentally-oriented young science. Psychology as science began with the measurement and analysis of perceptual processes whether we date its beginnings in the work of Weber (1824) or Fechner (1869), or the founding of the psychology laboratory at Leipzig by Wundt (1879).

Because receptors are tiny end-organs or nerve fibers the adequate stimuli for sensations were defined in terms of energies emanating from objects and capable of exciting specific end organs connected by afferent nerves to the central nervous system. Thus light rays stimulating the rods and cones are the adequate stimuli for everything perceived visually; mechanical stimuli resulting in deformation of the skin produce contact, light pressure, deep pressure, and pain; and sound waves impinging on the ear drum eventually stimulate the basilar membrane and the fibers of the Organ of Corti to arouse the auditory nerves and their central loci to make us aware of sounds. According to this first, older view, stimuli are narrowly and strictly defined; only the energies involved in stimulation are of moment, not the information they convey or their organization; receptors act more or less as independent units, no matter how closely they are packed together and regardless of branching and interlacing of afferent neurons; and sensory processes are real only to the extent that they stand up under pointlike stimulation and analytical introspection. Sensations on this basis reduce to their attributes--hue, brightness, and saturation in vision; pitch, volume, and loudness (for sure) in audition; and so on in the different sense modalities.

Analytical introspection brought order and simplification into Hume's unordered "self bundle of perceptions" which seemed, as Huxley pointed out, to arise out of nowhere and to disappear into nothingness. Order was explained by reference to the attributes of sensations which in turn were referable to dimensions or combinations of dimensions in the stimulus energies; and simplification was achieved by sticking to the "palpable" products of introspective analysis. Since only sensations and images were observed in the act of analyzing perceptions, meaning was said to arise from juxtaposition of inherently meaningless components. Perceptual objects as such had no place in introspective psychology, since they could be described in terms of their attributes which alone possessed "psychological" reality. Objects such as chairs and roses, and properties such as neatness, grace, and beauty were regarded as logical or technological constructs, not as immediate data of experience with which scientific psychology should deal (Titchener, 1909).

Brief as this historical review of the "atomistic" approach to perception has been, the reader may ask: Why spend any time at all discussing outworn and outmoded concepts and theories since the best way to forget them is to let them die of inanition by not mentioning them. There are several reasons for resurrecting older, erroneous views. First, the logic of old approaches may appear in new guises and may not be recognized as such unless the student has been alerted. Today we find the logic of compounding in learning theory and cognition where it is not easily detected as in perception. Second, essentially Lockian notions are still found in some approaches to sensory processes and

perception, e.g., in the assumption that some sensory presentations denote 'real' stimulus attributes and others are judgmental or inferential in nature although the latter are as predictable, vivid, and stimulus-bound as the former except that they do not correlate with pointlike stimulus energies, e.g., colored shadows, and anchor effects in perception and judgment. Third, since many students and laymen have access only to the philosophical and older psychological accounts of perception, it is necessary to mention them in order that they may be evaluated in the light of present-day advances.

#### Some Physiological Considerations

The concept of sensory process, as well as that of perception, has been broadened as knowledge has accumulated concerning its role in cognitive, effective, and emotional behavior. Effects of sensory deprivation, new knowledge concerning physiological interrelations of sensory, motor, and attentive (central) states, effects of feedback, learning, and needs, and the greater potentialities for stimulation in the environment have shown that perception is more than a complex of sensations and images. First it should be noted that the classic division of sensation and perception, with the latter arising out of the former through associative or compounding mechanisms, is now almost universally abandoned. It was made untenable by the phenomenological approach of Katz, the Gestalt psychologists, J.J. Gibson, and others in their treatments of color, space perception, and apparent movement. Thus Graham and Ratoosh (1962) point out that the use of the word 'sensory' as different from the word 'perceptual' can be justified only as a matter of convenience, not of content: "operationally and with respect to experimental procedures and outcomes the presumed differences between sensory discrimination and perceptual discrimination is meaningless" (p. 503). Since much of Graham's earlier work was concerned with what used to be called sensation as opposed to perception, this statement takes on added significance. There is, however, an essential difference between phenomenological and psychophysical procedures which was pointed out by Graham (1958): the former involve relatively unrestricted stimuli and responses while the latter usually involve a high degree of restriction in both. We shall return to this point later in our discussion of phenomenology.

The notion of simple, sensory deliverances of receptors fitted the physiological concept of the reflex arc according to which sensory processes were regarded as the culmination of afferent impulses initiated by stimulation of sense organs followed by transmission of neural impulses to the brain and culminating in a response. What occurred in the central areas when sensations were transformed into perceptions was supposedly determined by afferent impulses and the associated cognitive-imaginal processes aroused by them. This view did

not take into account central pooling, the influence of feedback from the organism's own activities, the gating action of the central nervous system on incoming impulses (Hernández-Péón, 1964), efferent control of receptor mechanisms (Lindsley, 1956), nor the conative and motivating involvements of sensory processes.

The more recent neurophysiological findings are epitomized in a summary of his work by Hernández-Péón. Through direct recording, this worker (1964) found that potentials from the cochlear nucleus, which represents the first synapse in the auditory pathway where impulses coming from the auditory nerve enter the brain, were reduced when mice were brought into the visual field of a cat. When the mice were removed the auditory potentials recovered their normal amplitude. He furthermore reported that impulses as low down as the spinal cord (in the spinothalamic tract) were also blocked when the cat was attending to a rat or to the odor of fish. Since even electric shocks applied to the skin were blocked it is evident that presumably intense, disagreeable stimulation may be inhibited when attention is directed to other stimuli. Generally, when attention is focussed upon a stimulus of any given sensory modality, transmission at the first synapse of other sensory pathways is partially blocked. There is also selective blocking within the same sensory modality for objects outside the focus of attention, e.g., exclusion of the curtain and stage contiguous to the screen as we watch a movie. Concurrently with inhibition there is also facilitation of signals generated by stimuli in the focus of attention according to Hernández-Péón. The simple reflex arc concept has also been shaken by demonstration of efferent control of receptor processes in practically all sense modalities (Edelberg, 1961). Lowered thresholds can result from tonic bombardment along efferent fibers. Lindsley (1956) pointed out that a new principle of behavioral control has emerged from work showing that "all sense modalities have some means of centrifugal control either at the level of the receptor itself, through reflex loops, at the first or second synapse, or more centrally located stations along efferent pathways" (p. 335). Efferent impulses may alter the excitability of receptors and thereby exercise a gating effect on afferent input.

Subcortical sensory blocking has also been demonstrated in man not only during attention to sensory input, but also when attention is focussed on ideas or central processes. Blocking, according to Hernández-Péón, was also achieved in human subjects by verbal suggestion: with electrodes implanted in the optic radiation, potentials evoked by flashes of light could be reduced or increased by suggesting to Ss that they would receive more or less intense flashes; and hypnotically induced anesthesia may result in selective decrease of excitability at the spinal level. Finally, there are also complex relations between arousal (vigilance) and sleep systems which may be either facilitating or inhibiting. Facilitation of some pathways or brain systems is accompanied by inhibition of others, even in sleep.

That sensory stimulation has a far wider significance than mere registration of impressions is shown by a review of literature dealing with effects of sensory deprivation (Miller, 1960). It is now known that sensory stimulation is necessary during early infancy for proper development of the visual system as a result of observations of chimpanzees raised in darkness (Riesen's study quoted by Miller) and such basic activities as urination and defecation in rats and color changes in kittens depend upon, or are speeded up, through appropriate types of stimulation during early life. Henry Head has pointed out somewhere in his writings that skin deprived of its normal afferent nerve supply becomes inflamed and otherwise abnormal showing that afferent nerves have nutrient as well as sensory functions. While perceptual disturbances have been stressed in studies of sensory deprivation there are also cognitive-emotional disturbances. Suedfeld, Grissom, and Vernon(1964) point out that failure in some studies to find conclusive evidence of cognitive decrement in problem-solving, learning, and reasoning tasks was due to the nature of the tasks which were short, structured, and definite. Using unstructured, variety-requiring, TAT-like tasks in which Ss were required to tell a story about material given them, these investigators found after 24 hours of sensory deprivation a highly significant loss in number of words and lowered speech rate. Socially isolated, but not sensorially isolated, Ss gave significantly greater numbers of words, but there was some loss in speech rate after 24 hours.

#### Perception, Affect and Motivation

That perception is more or less tinged with affect is generally recognized yet psychologists have been slow to include affect as a dimension of perception. In their "discrepancy-from-adaptation-level" theory of affect, McClelland and Clark (1953) have incorporated affectivity along with intensity and other dimensions as a dimension of sensory processes. Their theory is based on the assumption that stimuli to which the organism is adapted are neutral in the sense that they are neither too loud nor too soft, too bright nor too dim, too sweet nor lacking in sweetness, etc. They then add the assumption that small departures from level are pleasant and larger departures are increasingly unpleasant. Haber has tested this theory in the field of temperature (1958). Haber found for adaptation to temperatures in the vicinity of 33°C the maximum number of preferences for warm and cool came within  $\pm 1^\circ$  with some Ss preferring departures as much as  $3^\circ$  from adaptation level. Support for the McClelland-Clark theory also comes from a study by Connors (1964) utilizing a set of 7 randomly constructed visual figures to one of which Ss adapted by copying it each time before looking at all the members of the set. The members of the set were exposed two at a time and Ss were told to let their

gaze be drawn toward one or the other member of the pairs being exposed. Both the fixation times and the verbal reports of pleasantness showed that, in the case of one of the two adapted figures, there was a distinct preference for the figure next to it, while, in the case of the other adapted figure, the results were confirming but not so clear cut. Considering the tendency for visual stimuli of this sort to be neutral and the difficulty of scaling randomly constructed figures on a similarity continuum, the results must be considered highly suggestive and, in general, confirmatory of the McClelland-Clark theory in a new area.

Wherever there is affect, we can presume there is also motivation. The fact that tastes and odors are so heavily affectively loaded leads us to expect them to be strong motivators also, and this point has been stressed by Pfaffmann (1961; 1962). Using taste as an example, Pfaffmann has been one of the few psychologists to emphasize the motivating properties of sensory stimulation. He points out that stimuli elicit other functions than the commonly stressed discriminatory ones in classical sensory studies. This view has important consequences for the sensory control of behavior. Among them is his suggestion that the classical manifold of four tastes,--salt, sour, bitter, and sweet,--may be reduced to two behavioral classes: acceptance and rejection. However, some substances may be accepted at low but rejected at high concentrations, e.g., NaCl and sugar. No preference was shown by rats for acid and quinine solutions which start at about 50% at low concentrations and decline rapidly with higher concentrations. Sugar and salt show roughly inverted U-shaped curves of preference as a function of log mol concentration. Sweet seems to be the only substance that has a high preference rating with very strong concentrations. This leads to the well-known generalization regarding the pleasantness of tastes: sweet is predominantly pleasant, bitter is predominantly unpleasant, and salt and sour are intermediate. Direct confirmation of central effects from reinforcement have been found by Hernández-Péón: unrewarded stimuli such as repeated fish odors result in decreased activity in the olfactory bulb but if the cat is given fish to eat (positive reinforcement), the activity in the bulb increases (1964).

Affective values of colors and tones have been determined and reveal systematic relationships contrary to the popular belief that affective preference (aesthetics) is a purely personal matter. Guilford and his co-workers (Guilford and Smith, 1959) have mapped ischedonic contours for the hues as a function of their saturation and "brightness" and from these maps the domains of pleasant, unpleasant and neutral colors can be read. Earlier, Guilford (1954) mapped the domains of pleasant, neutral, and unpleasant pure tones as a function of loudness and pitch (intensity and frequency). Studies are needed in other sense modalities to furnish information for a taxonomy of their affective values as a function of dimensional variables.

We thus find that recent neurophysiological studies have shown the classical afferent-central-efferent one-way conduction is an over-simplified view of what goes on in the nervous system in the simplest sensori-motor behavior. There is now evidence for central gating of incoming impulses and efferent control of receptor thresholds. Furthermore, afferent input has a wider significance than mere registration of sensory contents. Sensory deprivation studies, results of de-afferenting the skin, and appreciation of the motivating properties of stimulation have served to place sensory input and perception in a wider neurophysiological and behavioral context. Finally, the affective and motivating properties of sensory qualities are now recognized by workers in sensory physiology and neurophysiology.

#### The Phenomenological Approach

While there were criticisms of Wundtian introspection as the sole method of studying psychological data in the latter part of the 19th and early in the 20th Century (Cf. Helson, 1925), it was not until the phenomenology of Husserl (1913) was modified to serve as a tool in psychological investigations by Katz (1911), Wertheimer (1912), and Rubin (1921) that the approach to perception changed from dimensional analysis to the description of molar properties of objects and temporal events. New dimensions and modes of color appearance, pattern and form perception, illusory movement, and figure-ground phenomena were studied in experimental laboratories by these and other workers. Even such tertiary qualities as beauty, grace, friendliness, and other "physiognomic characters" (Koffka, 1935) were held to be as immediately perceived as dimensional attributes of perception. Learning and judgment were relegated to a very minor, if any, role in determining what is perceived under various conditions. Every experience was valid in its own right and without regard to its 'reality' status. Thus movement perceived from rapid succession of stationary stimuli (phi phenomenon) was held to be as real psychologically as perception of actually moving objects. Phenomenology thus broadened the concept of what is immediately given in perception to include properties of complex stimuli and temporally extended stimuli such as melodies and trains of thought. This point of view has not been without effect on all areas of psychology (Cf. Snygg and Combs, 1949) and is still a vigorous movement as shown by the fact a whole session was devoted to "The phenomenological approach in psychology" at the International Congress of Psychology held in Bonn in 1960 (See for example, Herrman, 1961).

Impetus to the phenomenological approach was given by the great physicist, Ernst Mach (1886), and the philosopher-psychologist, von Ehrenfels (1890). The former maintained that all science, physics included, studies only sensations in various domains. But more important for psychology was his

demonstration that sensory contents appear in "space" and "time" forms which are over and above their qualitative contents, hence, they are formal in character. Thus, red and green squares possess the same formal space-form and different melodies having the same rhythm possess the same time-form. Ehrenfels regarded these space- and time-forms as supra-summative properties, not derivable from similar properties and activities of their parts and Köhler, following him, argued: ". . . it cannot be assumed that sensations of color and tone, and meanings of single words, are to be considered as 'parts' of space-forms, melodies, and higher thought processes; since the exact impression of a visual figure, or the specific character of a musical motif, and the meaning of an intelligible proposition, contain more than a sum of patches of color, tone sensations, and individual word meanings" (1924, p. ix). It was thus that organization in space and time was brought into psychology as a major problem in its own right.

The study of visual qualities was also extended beyond the boundaries of attributive analysis which yielded too few dimensions with which to encompass visual experience. Katz (1911) showed that the achromatic colors were not adequately described purely as a brightness series, but, like the chromatic colors, also were characterized by pronouncedness and insistence. The list of attributes of color was enlarged from the classical three, hue, brightness, and saturation, and modes of color appearance were described by Katz which possess varying numbers of attributes as listed in Table 1. Katz's work opened new vistas for visual science and has also provided the vocabulary for communicating with artists, scientists, and laymen about visual phenomena that were previously only known intuitively.

Similar advances were made by Wertheimer (1923; English translation, 1958) with respect to perception of form in his principles of visual organization. Gestalten tend to be as symmetrical, balanced, complete, and simple as possible. These tendencies can be summarized in the law of Prägnanz according to which Gestalten tend to be as 'good' as prevailing conditions allow. This law accounts for both accentuation or sharpening and levelling of configurational properties in brief exposures and over time in memory. Still another 'law' is that of "good continuation" according to which forms are perceived in such a way as to avoid sharp breaks or angles or abrupt changes in direction. Factors making for grouping of parts or elements (or sub-units) are nearness, similarity, and common fate. Wertheimer also stressed the step-wise character of many of our perceptions, e.g., in the tendency to perceive angles in broad schemata or categories, e.g., as either acute, obtuse or right. Thus an angle of 93° is seen as a deviation from a right angle or as a 'bad' right angle. Examples of these generalizations originally published by Wertheimer (1923; 1958) can now be found in most psychology textbooks (e.g., Woodworth and Schlosberg, 1954) and in books by psychologists writing on the psychology of art (Arnheim, 1954; Culamerian, 1963). By 1933 the writer culled 114 'laws'

Table 1

The attributes or dimensions of color classified with respect to the modes of appearance

Attributes	Modes of Appearance				
	1 Illuminant (glow)	2 Illumination (space filling)	3 Surface (object)	4 Volume (tridimensional)	5 Film (aperture)
1. Hue	x	x	x	x	x
2. Brightness	x	x	x	x	x
3. Saturation	x	x	x	x	x
4. Lightness			x		
5. Duration	x	x	x	x	x
6. Size	x	?	x	x	(x)
7. Shape	x	?	x	x	(x)
8. Location	x	(x)	x	x	not in depth
9. Texture	x	?	x	x	x
10. Gloss (Lustre)			x	x	x
11. Transparency (x)		x	x		
12. Fluctuation (flicker, sparkle, glitter)	x	x	x	x	
13. Insistence	x	x	x	x	(x)
14. Pronounced- ness	x	?	x	x	
15. Clearness <sup>1</sup>				x	
16. Affect	x	x	x	x	x

Adapted from The Science of Color, Committee on Colorimetry, Optical Society of America. New York: Thomas Y. Crowell Co., 1953, p. 151.

Parentheses indicate the attribute, in this writer's opinion, is indefinite for the mode in question and the question symbol stands for doubt as to whether or not the attribute is found in the mode.

<sup>1</sup>This attribute, first pointed out by Evans (1959) is regarded by him as "degrees of whiteness" (p. 66) in line with his example: by progressively diluting a glass of milk with water it finally becomes clear. The liquid does not go through any stage that can be called "gray". But the same may be done with black ink and so I would treat this as a case of 'turbid-clear' dimension just as transparency is the endpoint of an 'opaque-transparent' dimension.

from the Gestalt literature (Helson, 1933) concerning organization, patterning, and behavior of configurations under various conditions which Boering (1942) reduced to 14 generalizations.

Two experimental tests of configurational laws.-- Wertheimer's generalizations concerning the behavior of forms were based upon patterns that were observed and compared under ordinary conditions of viewing. Would these configurational laws stand up under different conditions, say under tachistoscopic exposure where what is perceived results from the 'inner dynamics' of the forms themselves? An experiment was accordingly performed by Fehrer (1935) in which 128 figures were exposed at intervals ranging from 40 to 680 c. Eight types of figures were employed: simple geometrical, dot figures, simple symmetrical and asymmetrical outline figures, complex asymmetrical, simple and complex 'broken' figures, and figures composed of parts that were complete units in themselves. Difficulty scores were computed for each of the 128 figures based upon the number of times they had to be presented for correct reproduction weighted by the time of exposure. Considering only the 10 easiest and the 10 most difficult figures it was found that all but one of the best figures were symmetrical, geometrical, closed figures, while 6 of the worst were dot figures, 7 were asymmetrical, and 7 were open line or dot figures. In general, difficulty increased with complexity. The types of errors made in reproducing the figures indicate how they tended to be perceived. There were 11 types of errors with frequencies of each in percents as follows: (1) levelling, 21.9; (2) more complicated than original, 18.4; (3) accentuation, 18.3; (4) greater symmetry introduced, 16.0; (5) qualitatively different figure, 8.2; (6) simplification, 7.6; (7) greater asymmetry than original, 6.7; (8) incomplete, 4.5; (9) nothing seen, 1.4; (10) formless or chaotic, 0.6; and (11) only position of 'something' indicated, 0.1.

From Fehrer's results it is seen that the laws of Gestalt were amply confirmed according to two different criteria: ease or spontaneity in perception and by the ways in which the stimuli changed when the times were too short for them to be perceived correctly. One new and wholly unexpected finding at variance with the law of simplicity was the large number of cases (18.4%) in which perceived figures were more complicated than the original figures. The tendency toward simplification under conditions of brief exposure seems intuitively sound on the premise that there isn't enough time for everything to be seen; but complication is difficult to understand when it does not contribute to symmetry, completeness or other configurational properties. Thus a semi-circle composed of 7 dots was reproduced correctly but with 9 dots more closely spaced together while parallelogram with gaps in two corners was reproduced with gaps in three corners.

In the second study by Mowatt (1940), the configurational

principles were tested in reverse, so to speak, by presenting figures to naive Ss with instructions to change them in any way to make them 'better' figures. Mowatt verified Fehrer's results, including the tendency toward complication. In this study 40 figures were employed of which one-half were symmetrical in one or more axes, one-half were asymmetrical, 8 were dot figures and the remaining 32 were line figures. One-half the line figures were closed or continuous and the other half were composed of unconnected lines or one line with one or more changes in direction. The figures least frequently modified in any way and their number in percents were: isoscales triangle, 72; circle, 70; hexagon, 62; rectangle, 62; and square, 60. The types of figures changed by all Ss (except one who did not change any of the 40 figures) were the open, asymmetrical and irregular figures. Asymmetrical figures were changed more than symmetrical and open more than closed. The changes were in the direction of greater simplification, symmetry, closure, good continuation, and complication or greater differentiation. In 94 percent of the cases something was added to the figures and in 3 percent was something subtracted. Only 3 percent of the figures were left unchanged. While accentuation and levelling appeared they were not counted because of the difficulty in making exact determinations concerning these changes.

The results of the Fehrer and Mowatt studies make it clear why configurational principles find expression in pictorial art where many of the techniques have developed by trial and error and by nothing more than intuition as to what is 'good' or 'bad' to the eye. The fact that these principles are found operative in tachistoscopic exposures as well as in Dauerbeobachtung seems to point to their locus in basic physiological mechanisms as claimed by the Gestalt psychologists.

Still other types of forms have been described, notably by Gibson (1951), who singles out the following 10 with illustrations of each:

1. Solid form: The margin or contour formed by two solid objects.
2. Surface form: Flat physical surfaces and their edges at various degrees of slant.
3. Outline form: The tracings of objects by means of pencil or pen on a surface.
4. Pictorial form: Photographs, paintings, and drawings.
5. Plan form: A plan view of the edges of a surface as in engineering drawings.
6. Perspective form: Outlines indicating a perspective-projection or view of an object.
7. Plane geometrical form: An imaginary closed line on an imaginary plane, although in actual representations composed of finite lines in given planes.
8. Solid geometrical form: Geometrical forms in three dimensions.

9. Projected form: A form in one-one correspondence with another form, e.g., an object and its shadow.

10. Nonsense form: Tracings on a surface which do not represent recognizable objects.

To Gibson's list we would add:

11. Dot and broken line forms: Forms made up of dots, short lines, and combinations of both such as were employed in the study by Fehrer referred to above.

12. Open forms: Incomplete drawings such as triangle with apex missing or surface forms with parts taken out such as a pie with a piece cut out.

13. Broken areas: Perceived as objects as in the Street Gestalt completion figures.

Object recognition depends largely upon form, especially in animals devoid of color vision, and the orientation of the form may determine what kind of object is perceived. Tinbergen (1951), using an ambiguous figure, which resembled a hawk from the left and a goose from the right, found that several species of birds exhibited fear reactions when the figure was moved to the left, accenting the hawklike appearance, but showed no such reactions when it was moved to the right, emphasizing the gooselike appearance. Although these birds were reared in isolation, their fear reactions to hawk-like appearance were immediate.

Direction and orientation, as well as other figural properties, influence our actions. Buhler (1951-52) has described how bees and ants use polarized light to determine the course angle necessary to return to hive or anthill. We should add it is possible that their behavior is guided instead by the position of the sun and earth landmarks. The pointing of the compass needle instructs the navigator of a ship which direction he must follow; and when entering a harbor, he must shift from instrumental indicators to landmarks, buoys, and other fixed objects to find his way (Buhler, 1954). Landmarks have a directive quality and a location quality which indicate "there's where I want to go." As odor may lead an animal to food, the names, directions, angles, and intersections of streets furnish a coordinate system that orient humans to various goals, near or far.

We should, however, point out that the directional qualities of landmarks, signs, and pointing devices are not inherent in them as such, but depend rather upon the contexts in which they appear. Up is away from the surface of the earth, whether at the north or south pole; right is on the side of the body away from the heart; and north is variously taken with respect to the magnetic pole or to the pole of the earth where Polaris is directly overhead. Even the visual vertical and horizontal, favored by our predominantly upright position and by the responses of the tactile-kinesthetic systems to gravitational forces, are influenced by contextual stimuli that can be made to distort these directions as perceived. Only recently have the background and contextual

stimuli responsible for establishment of spatial frames of reference been investigated, e.g., by the Ames group (Cf. Ittelson, 1952).

We are accustomed to think of directive stimuli as either spatial or cognitive, but often internal agents may be responsible for making it possible for stimuli to exert directive effects they would not otherwise have. Nissen (1951) gives the following example, instructive in this respect. "When carbon dioxide is added to the water of their aquarium, Daphnia ordinarily rise to the surface, but if the aquarium is lighted from below, the addition of carbon dioxide results in movement to the bottom of the tank. Without addition of carbon dioxide there is no orientation to light. The carbon dioxide supplies the sensitizing factor, light the directive component" (p. 356).

Although objects are oriented with respect to their environments, they are also internally differentiated so that directions may be laid down within the framework of the objects themselves. Both animate and inanimate objects, including man's artifacts, are structured internally in accordance with functional considerations. Tables, chairs, and beds stand on their legs, and the orifices of containers are at the top. What an impression of disorder prevails when such objects are overturned, and how difficult it is to learn to use shakers that discharge salt or pepper from their bases! The writer was astounded the first time he saw a snake of the species called "sidewinder" progressing sideways by first forming loops at right angles to its length, then elongating its body, forming new loops, and moving perpendicularly to the long axis of its body. It is often difficult to determine whether some modern cars are approaching or receding, because front and back look so much alike in the distance. We repeatedly perceive stimuli whose internal structures bear fixed relations to other objects. These relations impress themselves upon us and influence our responses later also by their residual effects. When object-structures and functions are not in accord with our expectancies, we are disturbed, and our reactions to them may suffer. Our spatial world is a synthetic structure built up by the pooled effect of present stimuli more or less modified by residuals operative from previous experience.

A more explicit attempt to combine the psychophysical with the phenomenological approach has been made by Gibson in a number of notable publications in which he has shown that many perceived object properties can be traced to stimulus conditions if a broader view of what is the stimulus is taken. Contrary to the prevalent view that light carries very little information and that space perception is a matter of learning and experience, Gibson points out that geometrical relations are given or specified by the light reaching the eye (1960, p. 25). Starting from the "optic array", he describes how multiply-reflected light in a clear medium (air) from opaque surfaces having imperfect smoothness gives rise

to different intensities and compositions in different directions when taken in small angular units. This yields an "optical texture". While the use made of the information in ambient light may depend upon the anatomy and physiology of the eye, stage of growth of the individual, and practice and attention, the point is that the information is there in the light to be perceived. The following types of information as well as their importance for behavior are said by Gibson to be present in the light stimulus:

(1) Presence or absence of texture. When absent in the downward direction it means loss of support and falling as shown by the visual cliff experiments of Walk, Eleanor Gibson, and Tighe (1957) wherein rats on an elevated wooden runway would not descend to an optically far surface having a denser and smaller texture than the optically near surface with its coarser texture;

(2) Pattern or form as well as various types of texture such as grainy, pebbled, mottled, aligned, irregular, sinuous;

(3) Closed contours yielding impression of solid, detached objects;

(4) Gradients of density of the same texture yielding impressions of distance. Finer textures appear more distant in accordance with the law of visual angle;

(5) Projective transformations of both contours and textures with movement of the organism provide guidance and control of locomotion;

(6) Invariance of optical arrays under a variety of conditions, e.g., from tri- to bidimensional projections and with changes in perspective due to locomotion of the observer. This last property may yield the ultimate solution to the problem of constancy and the stability of the phenomenal environment with changes in the retinal image.

Gibson has added to the usual spatial directions of up-down, forward-backward, and near-far, the dimensions of slant and tilt which he derives from differential texture gradients in the visual field (1950a; 1950b). Gibson and Cornsweet (1952) distinguish between geographical and optical slant: a desert plane is geographically flat but an individual looking into the distance sees an optical slant that increases from himself to the horizon. This slant is accompanied by a gradient of texture that becomes finer and finer as the eye travels from near to far. Retinal density gradient is important for optical slant and is built up, according to these writers, by successive retinal images and postural-gravitational stimuli as well. Whereas slant concerns rising or falling level from floor to ceiling or from ground to sky (down-up) and from wall to wall (right-left), tilt depends upon a clockwise or counterclockwise rotation of a surface with respect to either the up-down axis of the retina or the gravitational vertical. Measured differences found by Gibson and Cornsweet between optical and geographical slant indicate that they are functionally and phenomenologically different.

The effect of slant on depth perception was measured by Dusek, Teichner, and Kobrick (1955). Using a modified Howard-Dolman apparatus, Ss made equality settings between a standard and a variable by bringing the variable toward the standard in the third dimension. This procedure was repeated with the table at  $0^\circ$ ,  $1.7^\circ$ , and  $2.9^\circ$  slope on the hypothesis that angular relationships between the observer and the base-surround would influence depth acuity. As slope and eye-level increased, sensitivity also increased. The authors concluded that slope of terrain is important in discriminating distances out of doors. We find thus that phenomenological taxonomies provide new directions in which to look for explanations of behavioral data that otherwise could not be accounted for.

The concept of texture, like that of form, is not uni-dimensional. Hunter (1935) has described the texture of surfaces with a view toward measuring gloss as smooth, wavy, matt, blotter, pimpled or pitted, orange peel, brush-marked, checked, scratched (when surfaces are otherwise smooth), and yarn, which is a finer type of brush-marked. Except for types of texture mentioned in connection with their effects on gloss measurements, the varieties of texture remain to be evaluated in psychophysical terms. Theoretically, problems of texture raise questions concerning the manner in which the retinal mosaic of receptors is able to deliver the information on which differences of texture must ultimately rest. Practically, the control of textural qualities may require knowledge of the psychophysics of textures, as the psychophysics of color has proved to be of great importance in colorimetry.

Carrying the analysis to the tactile field, Gibson finds that many of the spatial properties of vision are found also in tactile-kinesthetic perception. Differences between the qualities and information yielded by active, searching touch and passive touch have been described by Gibson (1962). He finds an analogy between the former and ocular scanning. Active touch mediates the shape of objects which is over and above what is given by passively received contact and kinesthesia. Active touch involves joints and tendons in addition to the usual tactile components. In active touch the perceived qualities are referred to the object rather than to the skin or to the self. In this respect touch is more like vision where impressions are projected outward. Accompanying this outward reference is perception of stability as the hand moves over the stimulus. In spite of changing tactile sensations as the hand moves over objects the form of the object remains invariant, not the form of the hand or skin. New qualities are perceived in active touch such as rough-smooth, soft-hard, and various kinds of plasticity, elasticity, and viscosity,--the latter first reported by Katz (1925). Gibson also adds new "solid geometry" qualities of curvature, planarity, slant with respect to gravity, parallelity of surfaces, edges, angles, and corners as types of information yielded by active touch. And like vision, forms are transposable tactually when moved across the skin, and as pointed out

by Deutsch (1962), under rotation, with changes in size, and in right-left (mirror image) reversals.

The phenomenological approach also yields new sources of stimulation in touch. Thus Gibson (1962) distinguishes between brief deformations of the skin which give pressure, push, pat, slap, prick, and tap and prolonged deformations without displacement which give vibration, stretching, kneading, and pinching; and prolonged deformations with displacement which give scratching, scraping, rubbing, sliding, brushing, and rolling. We find that both the perceptual and stimulus domains of touch are greatly extended as a result of the phenomenological approach just as it has been in color vision.

The question as to whether or not phenomenal properties are constitutive, i.e., whether or not perceived objects and relations are governed wholly by anatomical (peripheral or central) mechanisms or to some extent by their phenomenal properties comes up again and again (Cf. Helson, 1964). Two studies by Rock and his coworkers show that perceived location rather than place of retinal excitation is the primary determinant of stroboscopic movement and visual grouping. In the study by Rock and Brosgole (1964) a test was made to determine if the Gestalt law of grouping by proximity is based on retinal or perceived proximity of elements. Dots separated by 4 in. horizontally and 3 in. vertically were perceived as columns due to the wider horizontal separations. The dots were then turned out of the frontal-parallel plane about their vertical axis and the reports of Ss changed from columns to rows at about 45° for monocular and at 55° for binocular viewing. Since the horizontal separation would equal the vertical at an angle of 41.4° the dots were perceived in columns after the horizontal distances were less than the vertical distances. From this and similar results in another experiment, they conclude that phenomenal grouping is not based (entirely?) on retinal location. To test for phenomenal constancy, Ss made estimates of the vertical and horizontal distances in inches. Constant estimates prevailed for binocular viewing almost up to the most extreme degrees of tilt which ranged from 50° to 60°. There was, however, much less constancy in monocular viewing. These writers assert that localizing autochthonous Gestalt factors in the stimulus configurations is a weakness in the configurationists' position.

In a second experiment, Rock and Ebenholtz (1962) tested the Gestalt explanation of apparent movement from stationary stimuli in terms of central physiological interactions between loci of excitations yielded by the two stimuli. If apparent movement can be perceived when only a single retinal area is excited or when there is not change in one of the areas this would argue against strict anatomical determination of apparent movement. It is usually assumed, they point out, that the minimum condition for apparent movement is that different spots on the retina be excited. Can movement be perceived when there is phenomenal difference but not retinal

difference? To answer this question several experiments were performed.

In the first experiment Ss moved their eyes from one slit to another to view spots of light in different places but in doing so the same foveal elements were excited. Under these conditions apparent movement was seen. Six of 10 Ss saw one object moving; the other 4 Ss saw two lights flashing on and off in their respective different positions. In a second part to this experiment different regions of retinal stimulation were phenomenally localized in the same place. By having S move his eyes so that a flashing light hit the fovea and then the periphery different retinal areas were stimulated but the light was seen in the same position. None of the Ss who saw movement in the first part of this experiment reported it here. There was no perceived movement here because the flash was seen in the same place in spite of exciting different retinal loci.

In a second experiment, conducted in three parts, a long luminous line moved back and forth while a short line flashed on and off in a given position. The short line was seen to move in a semicircular path about a taller luminous line in the third dimension, the latter moving back and forth. This effect parallels Duncker's induced movement where a stationary object in a frame of reference that moves appears to move also although there is no stimulation of different retinal points. When this experiment was repeated with the dimensions of the moving and stationary lines reversed so the short line only moved, no movement of the longer line was perceived. The third part of this experiment with phenomenal location of the stationary line uncertain and in conflict with observed motion of another line yielded ambiguous results. From all these observations it appears that change in phenomenal location must be given unequivocally for motion to be perceived whether or not different retinal areas are stimulated.

From the discussion up to this point it might be inferred from the results showing that phenomenal properties of objects influence other perceived attributes that they do so in all cases. There is much evidence to the contrary, e.g., different geometric figures have not been found to have significantly different absolute thresholds (Helson and Fehrer, 1932). But since there are many cases in which certain phenomenal properties may act against assumed anatomical determinants of perception as in the perception of depth from parallel lines which appear to diverge in stereoscopic presentations of the Zollner figure (Squires, 1956) it cannot be assumed that phenomenological properties are or are not constitutive without experimental proof that such is the case.

The information approach to form perception. --An entirely new approach to the quantification of dimensions of forms was made possible by the work of Shannon (1948) known as information-theory. This has served, among other things, to show that the concept of form is by no means simple

and unanalyzable. Michels and Zusne (in press) point out that quantification has now passed beyond the limits of information theory and there is a plethora of physical form measures. Information theory is based essentially on the extent to which ignorance is replaced by knowledge: the less likely the occurrence of an event or the greater the uncertainty or variance of an event, the greater is the information it imparts when it occurs. In this way of looking at things information is conveyed by surprise, change, improbability. Thus if we look at a solid black square on a white ground, information is conveyed only at the contours where white changes to black. In this figure, the corners are the places where the greatest amount of information is conveyed. The 'filling' inside the square merely repeats itself, if we take it point by point, and hence is redundant and conveys no information. Measurement of information is in 'bits', a bit being defined in terms of reduction of possible alternatives by one-half. Thus in throwing a coin, since there are two sides, the appearance of heads conveys one bit of information because the two possibilities have been reduced to one. To predict what will happen when 8 alternatives are possible, three bits of information are necessary. In short, the number of bits is merely the power to which the number 2 must be raised to equal the number of alternatives, or, conversely, it is the logarithm of the number to the base 2 (Cf. Miller, 1953; 1956).

What we have just said concerning information theory and form perception is not entirely accurate for it has become clear that, as Garner has emphasized: "The concept of redundancy can be dealt with in an exact manner only when we are dealing with sets of stimuli (italics ours), not with single stimuli, since redundancy is a measure (in uncertainty terms) of the extent to which an actual number of stimuli is smaller than the maximum number which could exist given the same number of variables with a given uncertainty . . . Uncertainty measurement deals with sets of stimuli, and probability distributions of these sets" (1962, p. 182). It is true, however, that a structured pattern is (more or less) redundant and a meaningless pattern is one that is random or non-redundant. The difficulty, as Garner points out, is in specifying or determining known amounts of redundancy in given figures. Strictly speaking, then, we should apply information theory to a stimulus only as a member of a class of stimuli defined in some way.

Having glanced briefly at the informational approach, let us return to the properties of forms that have been investigated quantitatively. Michels and Zusne (1965) list information content, linearity of contour, area, rotation, elongation, dispersion defined as perimeter squared divided by area, symmetry, sizes and relations among angles, curvature, area overlap, ratios of angles, and various relations of parts within figures and contours. Among these many possibilities of variation and measurement of forms Attneave (1957)

and Arnoult (1960) have shown that 87 percent of the variance in responses to forms can be accounted for by the number of independent sides, angular variability, symmetry, and the ratio of perimeter squared to area. So far as the study of forms is concerned, information theory has fostered the use of nonsense forms constructed by choosing points according to tables of random numbers. The result has been that there is often a seeming contradiction between informational and response criteria of what constitutes good, recognizable, or other-behaviorally determined criteria of forms, e.g., low threshold in short exposures, visibility under reduced illumination, discriminability, correct reproduction, etc. Thus according to Michels and Zusne increase in information usually leads to increased difficulty in performance, but Garner claims that more redundant figures are more complex and hence easier to discriminate. In short, while increased information might seem to be good in the sense of providing cues for easier recognition and discriminability this may not be the case when increased complexity makes for difficulty in correctly perceiving, remembering, and reproducing forms (Cf. Fehrer's study discussed above). Probably the resolution of these apparent contradictions lies in the fact that amount of information (complexity) and goodness of response measures are not monotonically related, i.e., up to a certain point increased information or complexity may aid and thereafter it is deleterious to ease of perception. In support of this conclusion is the fact that the hardest figures for color blind individuals to discriminate in tests of the Ishihara type are rounded ones; those with sharp breaks and corners are the easiest. Results of a study by Gaito (1959) bear directly on this point also. Exposure thresholds for four figures were determined. Using a straight line, arc of a circle, angle with apex upwards, and an incomplete box (long horizontal line with short verticals at the ends), Gaito found that line and arc of circle had the lowest thresholds and angle and 'box' the highest. These results are hard to interpret wholly on an information theory basis because the line yields information at two places (the ends), the arc at three places (ends and middle of the top), the angle at three places (ends and apex) and the 'box' at four places (where the short verticals join the horizontal and at their ends). According to Gaito an information theory interpretation is only partially correct in that it must be supplemented by consideration of critical detail, e.g., length of the two short vertical lines of the 'box' figure.

Another difficulty with information theory is that it does not take into account all stimulus relations, e.g., effects of rotation on figures, changes in size, and conditions of observation, nor does it make any reference to properties of the reacting organism or the individual differences among observers, e.g., decreased visual acuity of the color blind. Thus the change in a square to a diamond appearance when it is rotated so that it stands on a corner

is not accounted for by information theory and the new figures perceived in tachistoscopic exposures and under reduced illumination require a knowledge of how forms are perceived under various conditions in order to predict responses. These short-comings of information theory in dealing with perceived forms are not meant to convey the impression that this theory has no place in studying perception, judgment, and learning. A large literature shows that it has contributed much to all these areas (Cf. Miller, 1956 who cites many sensory studies elucidated by information theory) but it has not made unnecessary such behavioral studies as those of Fehrer, Mowatt, the Gestalt psychologists, and psychophysical studies of judgment and sensory processes.

#### Adaptation, Contrast, Assimilation and Constancy

Explanations of perceptual phenomena have been couched in terms of four mechanisms or processes conceived by earlier theorists to be more or less independent of each other. They are adaptation, contrast, assimilation, and constancy. Adaptation was traditionally conceived as a levelling process both in the sense of reducing differences between observed properties of stimuli and in the sense of a reduction in effectiveness of stimulation. A striking example of adaptation can be observed as follows: if a half-white, half-black field is fixated for a sufficient length of time the two sides of the field approach each other in lightness until, with complete adaptation, the two halves of the field are perceived as the same medium gray. Similarly, with complete adaptation to odoriferous, gustatory, tactile, and temperature stimuli there is disappearance of sensory quality. Complete neutralization, however, occurs only with weak or intermediate intensities of stimulation. Contrast has effects opposite to those of adaptation in that differences between stimuli are enhanced. Thus, the chromaticness of yellow is increased when juxtaposed to blue and a sound of medium intensity is louder following a softer sound. The third process, assimilation, refers to reversal of classical contrast and appears in spatial as well as qualitative aspects of perception. Thus Muller-Lyer ascribed the illusion that bears his name to a "confluxion" (streaming together) effect in opposition to contrast (repelling) as pointed out by Ladd and Woodworth (1915) and the lightening of chromatic areas by white lines and their darkening by black lines in the von Bezold figures has been ascribed to "mixture" or assimilation of adjacent stimuli (Helson and Rohles, 1959). Sensory blends within and across modalities, the latter called "complications" by Wundt, can also be included among assimilation effects.

The fourth aspect of perception which has seemed to require a separate underlying mechanism is the phenomenon of constancy which appears in the tendency of objects to hold

their color, size, shape and other properties under changing conditions of stimulation. Constancy is the behavioral analogue of physiological homeostasis wherein mechanisms act to maintain stable values of fundamental bodily processes such as the pH of the blood and internal body temperature. In many cases constancy refers to the perception of certain constant physical properties of objects, e.g., reflectance, size, and shape. Constancy, then, represents an isomorphism between certain properties of objects and their perceived properties when local or proximal stimulation varies. By local we refer to the receptors directly affected by object stimulation divorced from the influence of contextual stimuli.

Before proceeding to show that adaptation, contrast, assimilation, and constancy are not the results of independent mechanisms let us first take a closer look at phenomena of adaptation and its interrelations with the others.

The concept of adaptation in its narrowest sense has been restricted to the loss in sensitivity of peripheral sensory mechanisms (receptors) after relatively long exposures to stimulation. This view, like all definitions, is defensible if we are willing to overlook other important aspects of adaptive processes. Before the stationary level of sensitivity is reached in durative adaptation there are rapid, transient changes in sensitivity as shown in the steep initial parts of curves of dark adaptation for both the foveal and the peripheral areas of the retina. Everyday experience attests the rapidity of the initial stages of adaptation: on going into daylight from dark the initial blinding effect is over in a few seconds; on plunging into water the shock of the cold medium disappears almost instantly; and adaptation to intense sounds, tastes, and odors, while not as rapid as that to light and cold, is nevertheless significant long before steady-state adaptation has been reached. Except under contrived experimental conditions the adaptation of receptor systems changes from moment to moment, with every change in the environment and every change in bodily activities. It is doubtful if steady-state adaptation occurs during normal, waking conditions. Adaptation level fluctuates continually as sounds rise and fall, as the eyes turn from one part of the visual field to another, as foods are tasted in succession and as the temperature of the environing air changes or limbs are moved. Understanding the role of transient changes in adaptation can lead to greater insights regarding the nature of perceptual processes.

In addition to the fast, transient aspect of adaptation the classical view also neglects the sensitizing effects of adaptation. Adaptation to dark makes us more sensitive to light; adaptation to warmth makes us more sensitive to cold. Such effects have been attributed to 'contrast' mechanisms, but they cannot be divorced from adaptive mechanisms, if indeed, they are at all separate. While the temporal aspect of adaptation has been stressed in sensory physiology, phenomena of 'simultaneous' contrast prove that adaptive

mechanisms may act so fast as to appear to be nontemporal in character (Cf. Walls, 1960). We must, therefore, include in our view of adaptation transient as well as durative states, increased sensitivity as well as loss in sensitivity, and simultaneous as well as temporal phenomena of adaptation.

There is still another aspect of adaptation which has been neglected in studies of sensory adaptation, viz., central adaptation. It is very probable that there is not one but many types of central adaptation in view of the large variety of functions served by the brain. Both habituation and withdrawal symptoms in narcotics addiction must be attributed to central mechanisms. Even some sensory adaptations in the narrower, classical sense argue strongly for central as well as peripheral involvement. In this connection Aftanas and Zubek (1963) found that absence of tactual stimulation on an area of the skin for week resulted in increased tactual acuity while application of a constant light pressure resulted in decreased acuity. Since the effects lasted several days following the experimental treatment it appears that the phenomena were at least partly central in character. Stronger evidence for central adaptation was found by Aftanas, Marion and Zubek in a later study (1964) which involved interlimb transfer of effects of adaptation. An area 4 cm. in diameter on the forearm was covered by a plastic cup to insure absence of stimulation with 10 men Ss. A second group of 10 men Ss had constant pressure on the same area and a control group of 10 men Ss merely had a plastic open ring bandaged to this area. Each treatment lasted one week. Two-point threshold and tactual fusion were determined before and immediately after each of the conditions and also one and two days later. The same tests were also made on homologous and non-homologous areas of the contralateral arm. Fusion was tested by determining the critical frequency of percussion (CFP) (in number of air vibrations) necessary to perceive fusion.

It was found that absence of stimulation was followed by increased CFP on the seventh day on both the affected arm and to a lesser extent on the contralateral area. Higher CFP was found on the day following end of the experimental conditions on the affected area. No change was found in the control group or in the non-homologous area of the experimental group. Similar results were obtained with two-point threshold measurements: absence of stimulation resulted in a lower threshold (both CFP and two-points) and constant stimulation produced a decrease in tactual acuity (increased two-point threshold) while the control group showed no change. There was some transfer to the contralateral, homologous area (increased sensitivity) following the constant stimulus condition. There was no transfer to the non-homologous area of the contralateral arm and none in the case of the two-point threshold on the homologous area. In this experiment there were no perseverative effects on the first and second days following the stimulus treatments as contrasted with the first experiment in which effects persisted to some extent

for three days. Hence, the transfer effects for both increased and decreased sensitivity must be attributed to central as well as to peripheral adaptation. The authors explain the transfer effects in terms of level of background activity in somatic areas I and II of the right hemisphere and somatic area I of the left hemisphere: neural impulses enter these regions after isolation against a reduced background of heightened activity after constant stimulation with resultant effects on discrimination. Whether or not the brain mechanisms responsible for these effects are correctly described, the phenomena point to central as well as peripheral adaptations when conditions are made sufficiently compelling to induce durative modifications in the central processes.

It is apparent that the concept of adaptation must be extended beyond the classical definition if transient as well as durative portions of adaptation curves are taken into consideration, if simultaneous and successive sensitizing (contrast) and desensitizing effects of adaptation are considered, and finally, if central as well as peripheral phenomena are taken into account. The concept of adaptation thus embraces a wider range of phenomena and also furnishes a unitary frame of reference to relate phenomena that were formerly regarded as separate.

There are cogent reasons for regarding adaptation, contrast, assimilation, and constancy as manifestations of a single underlying mechanism. First is the fact that they are all mediated by the same receptor systems. Thus the rods and cones and their appurtenant neural elements are certainly involved in all four types of phenomena. It is hard to believe that the eye, the ear, the skin senses, taste, and smell mechanisms act one way when adaptation is in question, and in other ways when contrast, constancy or assimilation are in question. While inhibition may be responsible for contrast, and facilitation or summation for assimilation, as we shall argue later, this does not mean that new or different mechanisms are involved in contrast as opposed to assimilation or that adaptation and contrast are toto coelo physiologically different. Second it is not true that these characteristics of perception are independent. As pointed out above, adaptation to one stimulus or quality makes us both simultaneously and successively more sensitive to the complementary quality or stimulus, hence adaptation and contrast are inextricably related. Titchener (1909) long ago stressed the interrelations of adaptation and contrast in the various sense modalities: "In smell, the effect of adaptation is to increase our sensitivity for certain qualities, and to reduce or destroy it for others . . . . A sour applied to one side of the tongue brings out. . . the taste of a subliminal sweet applied to the other side" (pp. 136-7). In the same vein Gibson (1937) has enunciated the principle of adaptation with negative after-effect (contrast, in our terms) and the principle of color conversion (Helson, 1938), expresses the fact that adaptation and contrast occur together and are the results of a single visual mechanism.

What of constancy? Does it require the assumption of new or different mechanisms? Work by Bornemeier (quoted by Helson, 1943) showed that lightness constancy depends upon the state of adaptation of the eye. Constancy of color, size, and shape disappears if perspective and surroundings are obliterated by viewing objects through long, black tubes or if stimuli are seen as filling apertures in texturally homogeneous, neutral surrounds.

Color contrast, and assimilation (reversal of classical contrast) have been shown to lie on a single quantitative continuum in a series of studies by the writer and his co-workers (Helson and Rohles, 1959; Helson and Jcy, 1962; Helson, 1963; Steger, 1964). We have already referred to the lightening (darkening) of chromatic areas overlaid by white (black) lines as examples of assimilation. Reference to Fig. 1 shows that the lightening effect of white lines or the darkening effect of black lines on a gray surface is inversely related to the width of the lines and of the intervening gray areas between the lines. The transition from assimilation to contrast occurs with lines about 10 mm. wide; wider lines exert contrast effects. Contrast and assimilation are thus seen to be complementary and to lie on a single continuum divided by a neutral zone wherein there is neither contrast nor assimilation. However, when background reflectance is near line reflectance, e.g., white lines on near-white background, or black lines on near-black background, there is no contrast, only varying degrees of assimilation with all widths of lines and intervening areas as seen from Figs. 2 and 3.

A simple physiological model, based on generally accepted principles, seems to account for both contrast and assimilation as follows: we assume that small differentials in stimulation summate and large differentials result in inhibition of weaker by stronger neural impulses. On this basis assimilation occurs when neural impulses facilitate and contrast occurs when they inhibit each other in neighboring areas. This model explains the absence of contrast when the lines and backgrounds have nearly the same reflectances and also the stronger assimilation effects found with narrower lines and smaller intervening background areas. To explain the predominance of contrast effect with wide stripes or intervening areas we need only assume that within certain limits area acts like luminance, i.e., increase in area has the same effect as increase in luminance. In line with this assumption, assimilation should be replaced by contrast when the width of the lines increases relative to that of the intervening areas, a fact verified in Fig. 4. Reading vertically, it is seen that assimilation decreases and contrast increases as the intervening gray area increases for any given width of line. One final deduction from our physiological model has been verified experimentally: if large differentials in reflectance produce contrast and small differentials produce assimilation, there should be some intermediate differential that produces neither contrast nor assimilation and this is exactly what is found with lines in the neighborhood of 10 mm. on gray background as seen in Fig. 5.

Having seen that adaptation, contrast, assimilation, and constancy are interrelated we have achieved an economy in thinking about these four phenomena. A fifth phenomenon, figural aftereffects (FAE), must also be regarded as related to the betterknown phenomena of adaptation and contrast rather than as a phenomenon sui generis. FAE appears when figures are fixated and then compared with identical stimuli falling on neighboring retinal areas. Thus if a tilted line is fixated, a straight line appears tilted in the opposite direction (Gibson, 1933); if a square falling on the left of the fixation point is fixated for 20-40 sec. it is perceived to be smaller than an identical figure exposed on the right of the fixation point. In general, stimuli in the vicinity of previously fixated figures are repelled from the adapted region. Thus a figure exposed inside the contours of a fixated figure appears smaller while if exposed outside the fixated figure it appears larger, than identical figures on unexposed retinal areas (Kohler and Wallach, 1944).

The main figural aftereffects are so similar to older, betterknown adaptation and contrast effects it is hard to see why they have been regarded as a special class of phenomena. The repulsion of figures from adapted areas is analogous to the effects of anchors and backgrounds in phenomena of adaptation and contrast (Cf. Helson and Nash, 1960). Perhaps the most closely related phenomenon to FAE is the rotating spiral wherein a black spiral figure appears to expand during rotation and to contract when the disc stops moving. While it has been claimed that certain aspects of FAE are different from adaptation and contrast, no satisfactory theory has yet been devised to account for them as special phenomena. Viewed as cases of adaptation with negative aftereffect FAE is brought within the much wider context of more general, better understood principles.

A beginning in the direction of relating FAE to adaptation-contrast experimentally was made in 1952 by Elaine Graham whose work was later confirmed by other cited in the delayed publication of her results (1961). In this study Graham found that displacements of lines following adaptation to the inspection figure (IF) increased as a function of the brightness-contrast between the figure and its background. Absolute variations in luminance of background with contrast constant do not affect FAE. Investigations of other dimensions of test figures and their backgrounds, e.g., width or area vs. contour of IF, did not yield univocal results as pointed out by Graham. However, there can be little doubt that systematic, parametric studies of the dimensional attributes of FAE will bring this phenomenon within the domain of adaptation-contrast effects.

More recently, Deutsch (1964) has argued that FAE is produced by the mechanism responsible for simultaneous and successive contrast and he cites neurophysiological evidence of inhibitory interactions of adjacent cells to account for contrast and thereby for FAE. However, Deutsch's assumption

of interaction of adjacent areas is open to the same objections as the Kohler-Wallach electrotonic theory which cannot account for FAE when heteromodal phenomena are in question. Jaffe (1956) found that if the fingers are run along two raised diverging strips of aluminum and then along parallel strips, the latter appear to converge. If Ss view a strip of white paper on black background of the same width as the standard, parallel strips, there is no effect of vision on kinesthetic FAE but if the visual stimulus is wider or narrower than the tactile standard, the latter shows a contrast effect. Hence concurrent visual stimulation can induce significant kinesthetic FAE. Jaffe maintained that the electrotonic model, couched in terms of specific brain areas, could not account for heteromodal interactions because these would require a greater spread of currents in the brain than seems plausible. A similar argument against the electrotonic model has also been advanced by Moylan (1964) who found that if KFAE was tested, not by using the same fingers and hand for the I and T conditions giving contrast, but one hand for adaptation (I) and the other hand for testing (T) on parallel bars, a T bar narrower than the I bar was judged wider rather than narrower, hence reversed contrast. In the case where a non-adapted hand is used and KFAE is found, the effect cannot be explained by reference to a cortically satiated area. Moylan refers to "general contrast theory" as better able to account for these findings but his use of general contrast theory is vague. He seems unacquainted with Jaffe's formulation which is as follows:

In terms of . . . "adaptation level" one might assume that the action of the visual stimuli is not limited to visual (areas) alone. These stimuli contribute to a common pool of past and present effects of stimulation and thereby may produce alterations in all modalities . . . adaptation level does provide a potential basis for the explanation of intermodal influences in perception. This broader application is possible since a specific physiological mechanism has not been invoked that is limited to a single sensory process (Jaffe, 1956, p. 75).

The adaptation-level paradigm allows for pooling or interaction not only between adjacent sensory elements but also for interactions between cortical areas presumably as far apart as those of the two hands in Moylan's variation of KFAE.

#### Attention, Figure-Ground, and Distinctiveness

Almost every system of psychology has had to grapple with the fact that among the stimuli bombarding the organism

through every avenue of sense, some stand out in perception and elicit overt or covert responses while the rest serve only as background or filling material. In general, transient stimuli become focal while steady-state stimuli tend to be relegated to marginal status unless very intense. While changes in the environment provide many of the phasic stimuli to which we attend, most of the variation in stimulation comes from our own activities as we move about, turn our heads and eyes, make contact with various objects, listen to various sounds, sniff at odors, and so on. Similar considerations apply to emotional and cognitive states which are influenced by what we are perceiving from moment to moment. The role of attention, largely forgotten in later learning theories, was recognized at the beginning of the century by Thorndike (1898) who noted that at the beginning of confinement in puzzle boxes animals reacted to any and every part of the enclosure and only after some learning occurred did the animal shorten the time it took to obtain release from the box by concentrating its efforts (focalizing its responses) on the means of release. It is now recognized that a large part of the time and effort spent in learning are devoted to finding out what must be responded to in the learning situation.

In Wundt's system Klarheit and Deutlichkeit were used to characterize contents of consciousness and, influenced by these terms, Titchener first maintained that sensory processes are clear only when in the center of attention, the rest being unclear. Later clearness gave way to attensity as an attribute of sensation to make the list of attributes five in all, --attensity, quality, intensity, extensity, and protensity (duration). The doctrine of clearness or attensity was designed to render a descriptive account of attention in keeping with Titchener's position (following Wundt) that science only describes and does not use concepts denoting activities or meanings (Cf. Boring, 1942). Originally there were only two levels, clear and unclear, but later it was granted that there may be several grades of clearness between the clear and unclear.

The Gestalt psychologists objected to the clearness account of attention because it essentially involved the constancy hypothesis; the perceptual object is implicitly assumed to be the same, only changing its clearness value with changes in attention (Cf. Nelson, 1925, 356ff.). Thus the famous brain-babies figure which is first perceived as a convoluted, side view of a cerebral hemisphere, is later seen as a mass of intertwining babies. Titchener (1909) maintained that when brain was seen the babies were unclear and when the babies were seen, the brain was unclear. Other illusions were accounted for in the same way. The configurationists, on the other hand, maintained that there were two different phenomenal objects,--brain in the one case and babies in the other. The description in terms of clearness, they felt, did not square with what was actually perceived. In place of changes of clearness, the configurationists stress

the emergence of new structures, new patterns with changes in set, attitude, or with changes in attention.

The work of Rubin (1921) on figure-ground phenomena fitted so well with conclusions reached by the configurationists that they incorporated it into their system of psychology. Figure and ground are the two fields into which all perceptions divide. Qualities emerge from a general level, are figured, and predominate in perception while ground sets off the figured, differentiated parts of the field. Illusions of reversible perspective show how new phenomenal objects arise as one part of the field is figure, the other ground; when the field reverses so that what was figure becomes ground and what was ground becomes figure, new objects are perceived which may not have existed at all (in perception) before. Figure and ground differ not only in phenomenological properties, e.g., figure is harder, more thing-like, better formed, and more solid than is ground, but they also differ functionally: the limen for color induction is higher in the figure than in the ground and once a part of the field is perceived as figure it tends to be remembered and perceived again as figure. Since the simplest quality is perceived against a ground all experience is figural in character (Koffka, 1925).

The introspective and configurationists' accounts of attention are alike in being purely descriptive. Not until recently (Nachmias, 1958; Murdock, 1960; Helson, 1964) has the concept of attention as clearness or vividness been reformulated in a quantitative way. Replacing clearness and vividness the term "distinctiveness" has been employed by Nachmias and by Murdock as difference from level and this proves to be capable of quantitative definition and treatment. Whereas Nachmias and the present writer define distinctiveness in terms of difference from level, stimuli coinciding with level being least distinctive, Murdock uses a somewhat similar definition by defining distinctiveness as the sum of the differences in logs of any items of a group from all the others. The percent difference of any item would then be its total difference divided by the sum of the total differences of all items in the group. This definition yields maximal distinctiveness at the ends of a serially ordered set of items and minimal distinctiveness in the middle. The D-scale is not symmetrical even when all the items have equal intensities or are simply rank ordered (as in the case of a set of nonsense syllables) because of the log function,--items at the beginning of a series get higher distinctiveness ratings than do items equally far from the center at the end of the series.

The concept of distinctiveness has the advantage of being able to account for the distinctiveness of weak stimuli as well as strong stimuli since it depends upon distance from level which is an average function of all the stimuli. Thus Nachmias found that low frequency words along with high frequency words according to the Thorndike-Lorge word-count were remembered better than words of average frequency even

though the former were less familiar. The concept of distinctiveness can also be used to interpret contrast effects in reinforcement, thus bringing perception back into learning theory where it has been neglected for many years.

#### A Theory of Perception

A theory of perception must take into account the fundamental fact that perception, no less than other types of response, is an adjustive process contributing to the adaptation of the organism to its environment. The adjustive character of perceptual processes manifests itself in a number of ways. For example, in any viewing situation some stimuli are very bright, some very dim, and others are medium or neutral; similarly some sounds are loud, some soft, and others are medium. Moreover, a stimulus that is very bright in one situation may be dim in another and sounds that are soft in one situation may be heard as loud in another. Often changes in perceived intensity or magnitude are accompanied by changes in quality: a bright neutral light in a red surround turns to blue-green if its luminance is sufficiently decreased and a positive afterimage on a black background turns to its complementary color on a white background. Thus both magnitude and quality of sensory processes depend upon the level of adaptation which prevails from moment to moment. To be operational the concept of adaptation level must be strictly defined in quantitative terms if possible. The results of many experiments, including determinations of actually reported medium or neutral judgments of stimuli, point toward a weighted log mean as the best and most general quantitative approximation to adaptation level (Helson, 1964) although other definitions may be preferable in certain cases. Stimuli above AL have a given quality, stimuli below have the complementary quality, and stimuli near AL are neutral or of uncertain quality. In defining AL as a weighted mean we also assume that it is the pooled effect of all stimuli, inner as well as outer, acting on the organism.

It is evident that AL serves as the origin or zero of organic function. Since the value of AL is always positive, bipolar qualities and responses arise as positive or negative gradients from level. Afterimages, contrast, and adaptation effects can thus be positively accounted for without recourse to negative sensations, or higher level judgmental, illusory, or imaginative processes. Since the concept of pooling is central to AL theory and so many phenomena are associated with, and find explanation in their relations to, prevailing levels we shall consider a number of critical problems in the next section which is devoted to a discussion of various phenomena and consequences of the pooling model.

#### Phenomena and Consequences of the Pooling Mechanism

The organization, patterning, and complexity so char-

acteristic of perceptual processes arise from interactions of the simplest, basic dimensions and extend to the most complex formations. The dependence of absolute and differential thresholds on interactions of space, time, and intensity of stimulation have long been formalized in such laws as the law of photographic reciprocity ( $IT = k$ , where the symbols stand respectively for intensity, time, and a constant) and Ricco's law ( $AI = k$ , where A stands for area and the other symbols have the same meanings as before). That these laws depend upon pooling processes is almost self-evident for they express the fact that intensity may function for time or area or vice versa. There are many other such cases, e.g., the Tau effect (Helson and King, 1931) in which perceived spatial extents between three points stimulated successively on the skin depend upon the time intervals, and the kappa effect (Abe, 1935; Cohen, Hansel, and Sylvester, 1953) in which perceived temporal intervals between points stimulated successively depend upon the distances. In all these cases pooling occurs among basic dimensions of perception. The pooling manifested at absolute thresholds and in perception of temporal and spatial intervals must be ascribed to the neurophysiological mechanisms underlying sensory processes.

Pooling occurs also over more extended temporal intervals as shown by Bevan and Darby (1955) in their study of the reciprocity between frequency and magnitude of stimulation with lifted weights. Noting the reciprocity between frequency and magnitude implied by the weighted log mean definition of adaptation level (Helson, 1964) these workers determined the number of presentations required by a wide range of anchors with a constant core of series stimuli to yield a given value of adaptation level (AL), i.e., the value of stimulus judged to be medium. They found very good agreement between theory and experimental data when anchors were varied in weight and frequency of presentation over a wide range. Thus an anchor of 314.4 grm. presented 200 times for each presentation of the series stimuli yielded the same AL as an anchor of 1,010 grm. presented 1.16 times for each presentation of the same core stimuli. These results are significant in showing that it is possible to have the same AL under varying conditions of stimulation due to the pooling of frequency and magnitude of successively presented stimuli.

Pooling is also found among spatial attributes of stimulation. Often spatial properties of objects appear to be so stable as to be static and independent of their surroundings. However, constancies and illusions of form, size, and position have been shown to depend upon interactions with background or contextual stimuli which pool with focal stimuli to influence what is perceived. Thus Nellis (1958) found that shape constancy was highest when ellipses were viewed against normally oriented backgrounds, i.e., at right angles to the line of regard. Constancy decreased as background was turned more and more out of the frontal-parallel plane.

Hermans (1954) showed that as less and less of the field surrounding an object is visible by reducing vision from binocular to monocular to pinhole viewing apparent size of the object was reduced. With reduction of the visual field there are other changes that affect perceived size, e.g., changes in accommodation and convergence, in the amount of light entering the eye, and in size of the pupil. Reduction in apparent size of objects amounting to 33 per cent results when accommodation is maximal (near fixation) as compared with minimal accommodation (far fixation) as found by the writer (Helson, 1935). Similarly apparent size was shown to vary with changes in luminance by comparing objects in free vision with the same objects viewed through pinholes which excluded all light except that from the focal stimulus.

A test in reverse can be made of the influence of surroundings on apparent size as follows: according to Emmert's law the size of the afterimage is proportional to the distance at which it is projected. In other words, nearer fixation results in smaller, farther fixation in larger, perceived size of the afterimage in free viewing. But if the afterimage is viewed through a tube having a diameter only slightly larger than the image (Helson, 1936) the majority of the reports of perceived size are either equal or only slightly larger when projection distances are 2, 5, and 6 times original distance of fixation of the stimulus. Emmert's law did not apply, under these conditions, to perceived size of the afterimage but the measured size did obey this law. This striking departure of apparent from measured size shows that perceived size depends largely on the field conditions of viewing. The failure of the afterimage to increase in perceived size with increasing distance of the plane of projection in tubular vision shows that for Emmert's law to hold the image must be perceived in normal perspective relations. That normal perspective was not present appears from the protocols of the Ss who reported that the afterimage was always at the end of the tube, not at the actual distance of projection. It is also probable that accommodation was not relaxed in tube viewing and this may also have contributed to the failure of the image to increase in apparent size with increasing distance of projection since, as pointed out above, objects appear smaller with near fixation than with far fixation. It is thus seen that normal perspective, the presence of other objects, and relaxation of accommodation are necessary for size constancy and also for Emmert's law to be validated in perception.

Cross-modal pooling also occurs though it is usually less intimate than intra-modal interactions except for the phenomenon known as synesthesia where sensory processes in one modality fuse with those of another. The fusion is so complete that Ss use such expressions as "colored hearing" to describe their experiences. The pattern in Fig. 6 shows how one synesthetic individual, a young man in his 20's, perceived a portion of an orchestral composition.<sup>1</sup> He reported, in connection with this picture of his experience:

"I made this snap shot while listening very attentively to an orchestra . . . while there was constant action in what I 'saw', it was in this place (represented by the figure) that it slowed up enough for me to visualize it clearly and to remember the motifs at play. After making a pencil sketch of the arrangement of the various parts of the picture I later transcribed it in wash drawing to give it the texture it seemed to have. In this particular I have failed for I was unable to give it any luminosity or transparency that seemed to be part of it." He then went on to say:

"On analyzing it you will notice what I believe to be the melody and the counter-melody (the two horizontal 'waves' in the upper part of the figure) . . . The dominating volume of heavy instruments form a background and there, too, you find them in harmony or parallel (the vertical columns). The heavy 'wave' at the base must be the rhythm . . . I was surprised to discover purely from analysis that there were three separate parts to what I saw: the melody, the associated melody, and then the background or base notes. Lastly there was a distinctly removed thing (the rhythm). Action was portrayed by the melody and the rhythm. A lack of action seems to be portrayed in the background."

In a study of the influence of heteromodal anchors, Bevan and Pritchard (1964) found that visual anchor stimuli caused a downward shift in judgments of the loudness of tones when the former were sufficiently intense. But visual stimuli matched in intensity with the tonal stimuli functioned as weaker anchors, raising judgments of loudness instead of lowering them. Such effects may be due to inherent differences in intensity among the different sense modalities, failure of Ss to make good heteromodal matches, or there may be some loss in effective intensity when heteromodal comparisons are made. That there are inherent temporal differences among the sense modalities has been shown in judgments of auditory and visual durations by Behar and Bevan (1961) and by Goldstone and Goldfarb (1964). These workers found that when auditory and visual stimuli are of equal duration, the former are judged longer than the latter.

Some of the most important heteromodal interactions are found in spatial perception. Roelofs (1960) has made out a very strong case for the influence of kinesthetic input from eye movements on depth perception and localization in the visual field as shown in the following quotation:

The fundamental basis of optic localization is to be found in the adjustment impulses, both for the eyes and for the head. It is the tensions between the various adjustment impulses which constitute the physiological correlate of optic localization. Limiting ourselves to the impulses to ocular movements, we find that it is the tension between impulses to laterever-

sion which informs us as to what object is localized more to the left and what more to the right; it is the tension between impulses to sursumversion and those to deorsumversion that shows us which is higher and which is lower; it is the tension between impulses to convergence and those to divergence which teaches us which is nearer and which farther away. In the case of exocentral or relative localization we encounter tensions between adjustment impulses arising from various objects in the environment. In the case of egocentral or absolute localization we are confronted with tensions between the reflex gaze tonus and the adjustment impulses provided by the objects seen (1960, p. 214f.)

Although we may grant that input from the muscles of the eyes and head are correlated with perception of relative position, distance, and depth of visual stimuli, the question how tactile-kinesthetic impulses are translated into visual data remains. While the ultimate solution must eventually be sought in neurophysiological terms, for purposes of further behavioral investigations it may be necessary to abandon the classical belief in a self-contained, self-determined visual space. Except for a primitive visual expanse as suggested by the reports of individuals who have acquired sight for the first time in adult life, there is probably no purely visual perception of depth, distance, direction, or position.

Pooling is also exemplified in masking, inhibition, or suppression of data in one sense modality by those from another as in the case of suppression of pain by sound (Gardner, Licklider, and Weiss, 1960). These writers found that certain types of pain may be reduced or abolished by intense acoustic stimulation. They report that in 90 percent of 5000 'operations' (dental procedures?) sound stimulation was the only analgesic required. The greater the pain, the higher the intensity required to reduce the pain. In explanation of this effect they point out that parts of the auditory and pain systems come together in several regions of the reticular formation and lower thalamus. Even reduction of pain through relaxation, decreased anxiety, and diversion of attention can, they believe, be explained by assuming that acoustic stimulation reduces the gain of pain relays upon which branches of the auditory nerve impinge.

So far the discussion of pooling has been concerned with interactions of sensory data but pooling is not confined to interaction of impulses from peripheral systems only. Pooling also occurs between cognitive and affective systems on the one hand and sensory systems on the other. The influence of needs and other inner factors on perception was demonstrated by the New Look psychologists experimentally (Cf. the review of this movement by the writer, 1953). Effects of instructions on what is perceived argue for cognitive participation in

perceptual processes as shown in a study by Bevan, Maier, and Nelson (1963). Four groups of 75 Ss were asked to judge the number of beans in either a small or a large glass container under "figure" or "ground" instructions. Under figure instructions Ss were told to regard the beans and their containers "as a single organic unit set off from their surroundings" while under ground instructions Ss were told to "remember they are separate. The jar is a container . . . and can be thought of as part of the context or background, just as in this picture of the (Rubin) goblet . . ." (p. 465). There were three jars containing 60, 230, 410 beans. It was hypothesized that if the instructions succeeded in making the jars focal with their contents then the largest and smallest estimates should be with the large jar as figure and the small jar as figure, respectively, while the estimates with large jar as ground and small jar as ground should fall in between the other two in that order. The results plotted in Fig 7 show that these hypotheses were verified. An unexpected finding was that all the estimates were below the actual number of beans under all conditions. That jar size exerted a greater influence under the figural instructions than under ground instructions supports the assumption that focal stimuli have greater weight in perception and judgment than do background and residual stimuli when all other factors, e.g., areas order of presentation, etc., are equal.

We have so far considered interactions of focal-on-focal and contextual-on-focal stimuli. Can it be shown experimentally that residual stimuli from previous experience can affect perceived attributes of stimulation? Among the most important and difficult conditions to control in psycho-physical and sensory investigations are those in which preceding stimuli influence succeeding ones. In the experiment referred to above by Behar and Bevan (1961) on judgments of duration, the results for intramodal (visual) anchors clearly show residual effects of preceding stimuli. Durations of 1, 2, 3, 4, and 5 sec. were judged with anchors of 0.2 and 9.0 sec. duration. The order of anchor presentations was counterbalanced, some receiving the control condition first, others the short anchor first, and the rest the long anchor first, and so on. In Fig. 8 the results are plotted across all anchors (left panel) and for the condition given first (right panel). It is seen that each anchor is more effective when presented first. An analysis of variance based on extraction of sums of squares for Ss X conditions and a sequence X conditions interaction yielded highly significant Fs showing that there was a perseveration of one condition into the next.

Many psychologists have used "past experience" as an indiscriminate principle in explaining many perceptual phenomena, including individual differences in perception. That this principle cannot be safely invoked for all cases, especially where stimulus conditions are so compelling that residuals play little or no part in determining what is perceived, has been amply demonstrated by the Gestalt psychologists

(Wertheimer, 1923; 1958). One of the latest studies to come to the writer's attention shows that residuals may be of importance with respect to one attribute or task in a given stimulus configuration and not to another. Robinson, Brown, and Hays (1964) exposed critical letter patterns, geometrical figures, and representational patterns in pairs which were either in the same or in opposite orientations. One group of Ss had merely to report "same" or "different" and another group had to identify the two patterns which might be the same or different, e.g., square and triangle, or sailboat and package of cigarettes. Time thresholds were determined by using tachistoscopic exposures in ascending order. Thresholds were higher for novel than for familiar objects so far as identification went but not so far as same-different judgments were concerned. This was also true for letters differing in frequency of occurrence in English: identification thresholds were higher for the less frequent letters but the same-different thresholds were not significantly different. Thus the type of response or task demanded of Ss may determine whether or not residuals are of importance in perception.

It is frequently asserted that the manner of perceiving influences later behavior. It is well known that anchors exert predominant effects in perception. Do such anchor effects persist over time, i.e., do they persist as residuals to influence later perceptions? A study by Steger and the author (reported in Nelson, 1964a) furnishes evidence for the potency of previous anchor effects in later judgments of size as shown in the following experiments. In the first experiment four groups of Ss judged a series of black squares on white background during the impression or learning series. The squares ranged from 1.0 to 3.82 in. on a side and were judged in terms of a rating scale from very, very small to very, very large. The initial conditions for the four groups were as follows: (a) without anchor stimulus; (b) with an anchor at the geometric center of the series (1.96 in.); (c) with a 9.0-in. anchor; and (d) with a .30-in. anchor. The average size judgments are shown in Fig. 9 and are in line with expectations from known anchor effects: The squares were judged smallest with the largest anchor, largest with the smallest anchor, and intermediate with the anchor at the center of the series and with the no anchor condition. One week later Ss were called back to the laboratory and asked to identify the smallest, middle, and largest stimuli in the series from a much more extended series that ranged from .10 in. to 14.55 in. on a side presented in ascending and descending orders. As shown in Fig. 10, the residual effects of the anchors in the impression trials are evident after 1 week: The 9.0-in. anchor group picked the smallest set of three; the .30-in. group picked the largest set of three; while the two control groups picked sets intermediate in size between those of the other two groups.

The first experiment was replicated and extended in a second experiment with four new groups of Ss to determine the

relative potency of anchors as residuals, i.e., anchors given during the impression phase, versus anchors present during the recall phase. Two control groups were not given anchors during the impression phase but were exposed to the .30- and 9.0-in. anchors during the recall phase. One experimental group was given the 9.0-in. anchor during the impression phase and the .30-in. anchor during the recall phase; conversely, the other experimental group was given the .30-in. anchor in the impression session and the 9.0-in. anchor in the recall session. The results again show expected effects of anchors as seen in Fig. 11 where the stimuli recalled with the 9.0-in. anchor present were smaller (curves coded V and VIII in Fig. 11) than stimuli recalled with the .30-in. anchor (curves coded VI and VII in Fig. 11). Comparison of the curves for Groups VI and VII show that the .30-in. anchor during recall was more effective if it followed 9.0-in. anchor during the impression phase one week earlier than if no anchor was present during the impression phase. However, the 9.0-in. anchor in the recall phase following a .30-in. anchor in the impression phase did not yield significantly lower recall choices than under the control condition (Groups V and VIII).

Pooling of subliminal stimuli with resultant effects on perception of suprathreshold stimuli has been found with electric shock by Black and Bevan (1960), with sound intensities by Bevan and Pritchard (1963), and in visual size judgments by Boardman and Goldstone (1962). In all these cases stimuli below awareness threshold serving as anchors resulted in reports of higher or larger series stimuli than in the control condition without the subliminal anchors. Bevan has noted the importance of such results (1964) for several areas of inquiry: (1) since subliminal shocks too weak to elicit GSR were able to raise judgments of intensity of electrical stimulation it is apparent that there are "situations in which behavioral indices are more sensitive measures of mediating events than are the usual physiological measures"; (2) such results may imply that brain-stem mechanisms associated with arousal and vigilance are distinct from those related to anxiety and fear; (3) the absolute threshold cannot always be applied as a criterion in the identification of stimuli relevant for pooling nor as the limiting value for all sensory dimensions; this suggests in turn, that sensory scales are not absolute but relative since the origin of the scale is not a true zero; and (4) views of the way in which "unconscious" mechanisms influence behavior may need revision in so far as their role is similar rather than different from, as in psychoanalytic theory, supraliminal stimuli. In connection with the last point Bevan says:

. . . at least one device by which unconscious variables influence behavior is through their role in structuring the behavioral environment within which the behavior they influence occurs. Here their role is similar to that of supraliminal var-

iables and the behavior, far from being irrational, (as in Freudian theory) is not only rational but appropriate to the circumstances as the behaving individual perceives them (1964, p. 97).

The problem of relevance.--In discussing pooling both within and across sense modalities it is obvious that not everything pools to form level and that there are limits to the pooling process. In general there is greater interaction among elements in the same modality than in different modalities and distance in space and time is known to reduce interaction. In proposing the pooling of focal, background, and residual stimuli as the mechanism by which adaptation levels are established interaction of these classes of stimuli was limited to those belonging to the "same universe of discourse" (Helson, 1964b). Later demonstrations of cross-modal interactions and the influence of subliminal stimuli on perception and judgment showed that pooling was even more general than I had supposed it to be originally. The pooling model may be used to determine the limits or absence of pooling just as the normal curve of distribution is used in determining whether or not a die is loaded or normal. The problem of relevance is not a simple one since it concerns many questions that may be asked. We shall consider two experiments illustrative of the experimental approach to problems of relevance in the field of vision.

In the first experiment by Bevan and Pritchard (1963) a series of rectangles ranging from a square 5 X 5 cm. to 4.4 X 5.6 cm. was presented to Ss with instructions to report on departures from squareness using an anchor 4.0 X 6.0 cm. The results from several experimental groups given the rectangles in vertical, horizontal, and intermediate orientations all plotted below the control group without anchor, i.e., the rectangles were judged to be more square with anchor than without. When a circle having the same diameter as the side of the square and an ellipse with axes of 4.0 X 6.0 cm. which were the same as the sides of the rectangle anchor were used, no anchor effect was found in judgments of the rectangles. Hence it was not the proportionality of the axes of the anchors but the phenomenal likeness of the anchors to the series (judged) stimuli that determined whether or not they were effective as anchors. The question then arose whether or not a stimulus must be not only the same shape but also the same size and color as the series stimuli in order to be effective (relevant) as anchor and so rectangles one-fourth and four times the area of the original anchor and one having the same area but differing the color (gray instead of black) were introduced. Neither the small nor the large nor the differently colored stimuli exerted statistically significant anchor effects. Relevance thus is in large measure determined by dimensional similarity to the stimuli being judged.

Since several dimensions are usually present in psycho-physical and perceptual situations and it may not always be easy or possible to vary one while holding the others constant,

Turner and Bevan (1962) varied two of the three dimensions of size, shape, and color of visual stimuli, holding the third constant. Ss were required to judge all three dimensions but anchors were introduced in only two of the three at any time. In other words, one group of Ss was given a series of rectangles with anchors in the shape and size dimensions but not in the color (gray) dimension, a second group was given anchors in the color and shape but not in the size dimension, and a third group was given anchors in the color and size but not in the shape dimension. Each group could thus provide control data for the dimension that was uninfluenced by anchors. The results clearly show that when anchors are present in two dimensions, these dimensions show typical anchor effects while the third dimension, uninfluenced by anchors, show only the usual series types of judgments. Moreover, when high anchors (above series stimuli as in the case of size and shape) and low anchors (below series stimuli as in the case of color) are simultaneously presented the response curves should be farthest from the control curves at the upper end in the former case and at the lower end in the latter case and this was actually found. It is thus evident that several adaptation levels are simultaneously operative more or less independently of one another when multidimensional stimuli are being judged. This conclusion has also received support in a study of aesthetic responses to paintings that were judged with respect to several different dimensions (Mouton and Helson, reported in Helson, 1964).

Whether or not stimuli are relevant can be determined from their effects on adaptation levels and the degree of relevance can thus be quantitatively specified. A paradoxical anchor effect in lifted weights has bearing on the question of relevance or the question of when and to what degree stimuli pool with other stimuli to affect AL. It is known that anchors below the mean of a series of stimuli cause an upward shift in judgments of weights, hence a downward shift in AL. It is also known that AL for series stimuli alone, i.e., with anchor equal to zero, is usually near the mean of the series stimuli. Now if anchors are made lighter and lighter the value of AL should decrease but at some value there should be an inflection point and still lighter anchors should have less and less effect on AL as their value approaches zero because AL is reverting to the series AL. This deduction was tested in an unpublished experiment (Helson and Masters). Weights of 100, 150, 200, 250, and 300 grm. were employed as series stimuli and weights of 200, 100, 50, 25, 12.5, 6.25, 3.12, and 1.55 grm. were employed as anchors in a randomized design. AL with no anchor was found to be 193 grm. and lighter anchors resulted in lower values of AL until AL was minimal (159 grm.) with an anchor of 25 grm. (Cf. Fig. 11). Below 25 grm. the anchors exerted less and less influence so that with an anchor of 1.56 grm. the value of AL was practically the same as the series AL (171 grm.). The paradox of lighter anchors raising the value of AL after a certain point disap-

pears when we remember that the series AL is higher than AL with anchors below the mean of the series. The experimental data fully supported the deductions from theory and indeed the theory made the experiment unnecessary except that the exact value of the inflection point had to be determined empirically. This result also tells us that if subliminal stimuli that lower AL are carried sufficiently far below absolute threshold their effect on AL will be less and less until the series AL is approached. Studies are now under way to investigate inflection points with subliminal anchors using sound, electric shock, and visual stimuli.

Are there inflection points in the effectiveness of anchors above series stimuli? This question was also investigated in the study just discussed. In the case of lifted weights it is reasonable to assume when anchors become so heavy vis-a-vis series stimuli as to require different sets of muscles and stances in lifting they will exert less effect on AL. Reference to Fig. 11 shows that the highest AL of 323 grm. was reached with an anchor of 1600 grm. But with the heaviest anchor of 2879 grm. AL dropped to 309 grm. Whether 1600 grm. is a true inflection point at the upper end of the scale and the drop in AL with 2879 grm. anchor is real remains to be determined experimentally. In the case of light and sound it is doubtful if there are inflection points with anchors above the series stimuli unless there are different modes of seeing and hearing with extremely intense stimuli than with stimuli of moderate intensity.

We thus see that whether or not stimuli are relevant depends upon the extent to which they pool with other stimuli to affect ALs. In order to know the value of AL operative in any given situation it is necessary that Ss be exposed sufficiently to stimuli in order to become more or less adapted to them. AL effects appear most clearly when different sets of conditions can be compared. An experiment by Helson and Bevan (1964) bears on these points. Ss were required to estimate the areas of central black areas relative to their white margins with materials simulating printed pages since it is known that amount of printed material on a page is usually greatly overestimated as pointed out by Paterson and Tinker (1938). In our study total field size (black plus white areas) did not prove to be a significant variable when each group judged with only a single field size. But when Ss judged constant black central areas against different overall field areas errors of overestimation were found to be inversely related to total field area, the largest errors occurring with the smallest backgrounds. Errors of overestimation were largest for all field areas when the central black area was 53% of the total area, next when it was 81%, and least when it was 21% of the total area as seen in Fig. 12. From these findings we conclude that in order for a variable to make itself manifest it must vary within the experience of each S. In other words, if the role fo many background or contextual factors is to be identified, experimental designs must be employed in which stimulus variables are manipulated within

rather than across groups (Helson and Bevan, 1964, pp. 340-341). If adaptation effects are very pronounced they can be demonstrated across groups but it is unsafe to conclude that level is not affected by a variable unless a within groups design has shown this to be the case.

### Summary

We conclude this chapter by noting that perception now embraces phenomena ranging from simple sensory processes to complex, patterned formations having cognitive and affective components. Modern advances in neurophysiology have shown that perception involves more than central elaboration of afferent impulses terminating in the brain; rather, it is the product of afferent-central-efferent interactions in which centrifugal as well as centripetal impulses determine what is focal, what is background, or is entirely excluded from notice. On the phenomenological side, new attributes and qualities have been discovered in the various sense modalities and new sources of stimulation have been found to account for many of them.

Phenomena of adaptation, contrast, assimilation, constancy, and satiation or figural aftereffects were shown to be products of a single underlying process that is essentially adaptive in nature. A quantitative theory involving interaction or pooling in both space and time and across as well as within sense modalities has been found to provide an operational approach to problems of perception. Among the more important problems being investigated within this framework are the extent and limits of the pooling process. The solution to many problems, such as effects of anchoring stimuli and what is or is not relevant in judging classes of stimuli lies in further exploration of pooling processes.

References

- Abe, A. Experimental study on the correlation between time and space. Tohoku Psychologica Folia, 1935, 3, 53-68.
- Aftanas, M., and Zubek, J.P. Long-term aftereffects following isolation of a circumscribed area of the skin. Percept. mot. Skills, 1963, 17, 867-870.
- Aftanas, M. and Zubek, J.P. Interlimb transfer of changes in tactual acuity following occlusion of a circumscribed area of the skin. Percept. mot. Skills, 1964, 18, 437-442.
- Arnheim, R. Art and visual perception. Berkeley: University of California Press, 1954.
- Arnoult, M.D. Prediction of perceptual responses from structural characteristics of the stimulus. Percept. mot. Skills, 1960, 11, 261-268.
- Attneave, F. Physical determinants of judged complexity of shapes. J. exp. Psychol., 1957, 53, 221-227.
- Attneave, F. and Arnoult, M.D. The quantitative study of shape and pattern perception. Psychol. Bull., 1956, 53, 452-471.
- Behar, I., and Bevan, W. The perceived duration of auditory and visual intervals: Cross-modal comparison and interaction. Amer. J. Psychol., 1961, 74, 17-26.
- Bevan, W. Subliminal stimulation: a pervasive problem for psychology. Psychol. Bull., 1964, 61, 81-99.
- Bevan, W. and Darby, C.L. Patterns of experience and the constancy of an indifference point for perceived weight. Amer. J. Psychol., 1955, 68, 575-584.
- Bevan, W., Maier, R.A. and Nelson, H. The influence of context upon the estimation of number. Amer. J. Psychol., 1963, 76, 464-469.
- Bevan, W. and Pritchard, Joan F. The effect of subliminal tones upon the judgment of loudness. J. exp. Psychol., 1963a, 66, 23-29.
- Bevan, W. and Pritchard, Joan F. The anchor effect and the problem of relevance in the judgment of shape. J. gen. Psychol., 1963b, 69, 147-161.
- Bevan, W. and Pritchard, Joan F. The effect of visual intensities upon the judgment of loudness. Amer. J. Psychol., 1964, 77, 93-98.
- Bevan, W. and Turner, E.D. Assimilation and contrast in the estimation of number. J. exp. Psychol., 1964, 67, 450-462.
- Boring, E.G. The physical dimensions of consciousness. New York: Appleton-Century-Crofts, 1933.
- Boring, E.G. Sensation and perception in the history of experimental psychology. New York: D. Appleton-Century, 1942.
- Buhler, K. The skywise and neighborwise navigation of ants and bees. Acta Psychologica, 1951-52, 8, 225-263.
- Buhler, K. The essentials of contact navigation. Acta Psychologica, 1954, 10, 278-316.

- Cohen, J., Hansel, C.E.M., and Sylvester, J.D. A new phenomenon in time judgment. Nature, 1953, 172, 901-903.
- Connors, C.K. Visual and approach motives as a function of discrepancy from expectancy level. Percept. mot. Skills, 1964, 18, 457-464.
- Crespi, L.P. Quantitative variation in incentive and performance in the white rat. Amer. J. Psychol., 1942, 55, 467-517.
- Crespi, L.P. Amount of reinforcement and level of performance. Psychol. Rev., 1944, 51, 341-357.
- Deutsch, J.A. A system for shape recognition. Psychol. Rev. 1962, 69, 492-500.
- Deutsch, J.A. Neurophysiological contrast phenomena and figural aftereffects. Psychol. Rev., 1964, 71, 19-26.
- Dusek, E.R., Teichner, E.H., and Kobrick, J.L. The effects of the angular relationships between the observer and the base-surround on relative depth-discrimination. Amer. J. Psychol., 1955, 68, 438-443.
- Edelberg, R. The relationship between the galvanic skin response, vasoconstriction, and tactile sensitivity. J. exp. Psychol., 1961, 62, 187-195.
- Ehrenfels, C. von. Ueber Gestaltqualitaten. Vierteljahrsschrift F. wiss. Philosophie, 1890, 14, 249-292.
- Evans, R.M. Eye, film, and camera in color photography. New York: John Wiley and Sons, 1959.
- Fehrer, E.V. An investigation of the learning of visually perceived forms. Amer. J. Psychol., 1935, 47, 187-221.
- Fitts, P.M. and Switzer, Gail. Cognitive aspects of information processing: 1. the familiarity of S-R sets and subsets. J. exp. Psychol., 1962, 63, 321-329.
- Gaito, J. Visual discrimination of straight and curved lines. Amer. J. Psychol., 1959, 72, 236-242.
- Gardner, W.J., Licklider, J.C.R., and Weisz, A.Z. Suppression of pain by sound. Science, 1960, 132, 32-33.
- Garner, W.R. Uncertainty and structure as psychological concepts. New York: John Wiley & Sons, 1962.
- Gibson, J.J. Adaptation with negative after-effect. Psychol. Rev., 1937, 44, 222-244.
- Gibson, J.J. The information contained in light. Acta Psychologica, 1960, 17, 23-30.
- Gibson, J.J. Observations on active touch. Psychol. Rev., 1962, 69, 477-491.
- Goldstone, S., and Goldfarb, Joyce L. Direct comparison of auditory and visual durations. J. exp. Psychol., 1964a, 67, 483-485.
- Goldstone, S., and Goldfarb, Joyce L. Auditory and visual time judgment. J. gen. Psychol., 1964 b, 70, 369-387.
- Graham, C.H. Sensation and perception in an objective psychology. Psychol. Rev., 1958, 65, 65-76.
- Graham, C.H. and Ratoosh, P. Notes on some interrelations of sensory psychology, perception, and behavior. In Psychology: A study of a science. New York: McGraw-Hill Book Co., 1962.

- Graham, Elaine H. Figural after-effects as functions of contrast, area, and luminance of the inspection-figure. Psychologica, 1961, 4, 201-208.
- Guilford, J.P. System in the relationship of affective value to frequency and intensity of auditory stimuli. Amer. J. Psychol., 1954, 67, 691-695.
- Guilford, J.P., and Smith, Patricia C. A system of color preferences. Amer. J. Psychol., 1959, 72, 487-502.
- Gulamerian, N.B. The language of a work of art. New York: Utrecht Lines, 1963.
- Hebb, D.O. The organization of behavior. New York: Wiley, 1949.
- Helson, H. The psychology of Gestalt. Amer. J. Psychol., 1925, 36, 342-370.
- Helson, H. Demonstration of pupillary, accommodative, and consensual reflexes, through changes in apparent size of a pinhole. J. gen. Psychol., 1935, 13, 186-188.
- Helson, H. Size-constancy of the projected after-image. Amer. J. Psychol., 1936, 48, 638-642.
- Helson, H. Fundamental problems in color vision. I. The principle governing changes in hue, saturation, and lightness of non-selective samples in chromatic illumination. J. exp. Psychol., 1938, 23, 439-476.
- Helson, H. Some factors and implications of color constancy. J. opt. Soc. Amer., 1943, 33, 555-567.
- Helson, H. Perception and personality--a critique of recent experimental literature. Report No. 1, Project No. 21-0202-0007, USAF, School of Aviation Medicine, Randolph Field, Texas, 1953, 1-55.
- Helson, H. Studies of anomalous contrast and assimilation. J. opt. Soc. Amer., 1963, 53, 179-184.
- Helson, H. Current trends and issues in adaptation-level theory. Amer. Psychologist, 1964 a, 19, 26-38.
- Helson, H. Adaptation-level theory: an experimental and systematic approach to behavior. New York: Harper and Row, 1964 b.
- Helson, H. Constancy. In International Encyclopedia of the Social Sciences, (in press).
- Helson, H. and Bevan, W. An investigation of variables in judgments of relative area. J. exp. Psychol., 1964, 6, 335-341.
- Helson, H., and Fehrer, E.V. The role of form in perception, Amer. J. Psychol., 1932, 44, 79-102.
- Helson, H., and Joy, V. Domains of lightness assimilation and contrast effects in vision. Psychol. Beitr. 1962 , 6, 405-415.
- Helson, H., and King, S.M. The Tau effect--an example of psychological relativity. J. exp. Psychol., 1931, 14, 202-217.
- Helson, H., and Nash, M.C. Anchor, contrast, and paradoxical distance effects. J. exp. Psychol., 1960, 59, 113-121.
- Helson, H., and Rohles, F.H., Jr. A quantitative study of reversal of classical lightness-contrast. Amer. J. Psychol., 1959, 72, 530-538.

- Hernandez-Peon, R. Psychiatric implications of neurophysiological research. Bull. Menninger Clinic, 1964, 28, 165-185.
- Herrmann, T. Die Phanomenologische als einer kritische Methods. Acta Psychologica, 1961, 19, 522-527.
- Heuven, J.A.C. Ueber das Schatzen der Grossen von Kreisscheiben: 11. Z. F. Psychol., 1942, 153, 81-90.
- Hunter, R.S. A new gloss comparator and a study of different types of gloss effects. Washington, D.C.: Circular of the National Paint, Varnish and Lacquer Association, Inc., 1935, No. 493, 268-280.
- Husserl, E.G. Ideen zu einer reinen Phanomenologie und phanomenologischen Philosophie. Jahrb. F. Philosophie und phanomenologische Forschung, 1913, 1, 1ff.
- Huxley, T.H. Hume with helps to the study of Berkeley. London (England): MacMillan and Co., 1901.
- Ittelson, W.H. The Ames demonstrations in perception. Princeton N.J.: Princeton University Press, 1952.
- Jaffe, R. The influence of visual stimulation on kinesthetic figural aftereffects. Amer. J. Psychol., 1956, 69, 70-75.
- Katz, D. Die Erscheinungsweisen der Farben und ihre Beeinflussung durch die individuelle Erfahrung. Z. F. Psychol., 1911, Erg. Bd. 7.
- Katz, D. Der Aufbau der Tastwelt. Leipzig: Barth, 1925.
- Koffka, K. Perception: An introduction to the Gestalt-Theorie. Psychol. Bull., 1922, 19, 531-585.
- Koffka, K. Principles of Gestalt Psychology. New York: Harcourt, Brace, and World, 1935.
- Kohler, W. Die Physischen Gestalten in Ruhe und im stationaren Zustand, Braunschweig: Vieweg & Sohn, 1924.
- Kohler, W., and Wallach, H. Figural after-effects: an investigation of visual processes. Proc. Amer. Philos. Soc., 1944, 88, 269-357.
- Kohler, I. Reizstatistik und Wahrnehmung. Acta Psychologica, 1961, 19, 537-543.
- Ladd, G.T. and Woodworth, R.S. Elements of physiological psychology. New York: Charles Scribner's Sons, 1911.
- Lindsley, D.B. Physiological psychology. Annu. Rev. Psychol., 1956, 7, 323-348.
- Locke, J. An essay concerning human understanding. London: G. Bell & Sons, 1913 (originally published in 1690).
- Mach, E. Analysis of Sensations. Chicago: Open Court, 1914, (German ed. Jena: 1886).
- McClelland, D.C., Atkinson, J.W., Clark, R.A., and Lowell, E.L. The achievement motive. New York: Appleton-Century-Crofts, 1953.
- Michels, K.M. and Zusne, L. The metrics of visual form. Psychol. Bull., 1965, 63, 74-86.
- Miller, G.A. What is information measurement? Amer. Psychologist, 1953, 8, 3.11.

- Miller, G.A. The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychol. Rev., 1956, 63, 81-97.
- Miller, J.G. Information input overload and psychopathology. Amer. J. Psychiat., 1960, 116, 695-704.
- Mowatt, Marian H. Configurational properties considered "good" by naive subjects. Amer. J. Psychol., 1940, 53, 46-69.
- Moylan, J.J. Kinesthetic figural aftereffects: satiation or contrast. J. exp. Psychol., 1964, 67, 83-90.
- Murdock, B.B. The distinctiveness of stimuli. Psychol. Rev. 1960, 67, 16-31.
- Nachmias, J. The effect of stimulus-heterogeneity on free recall. Amer. J. Psychol., 1958, 71, 578-582.
- Nissen, H.W. Phylogenetic comparison. In Handbook of Experimental Psychology, (S.S. Stevens, ed.). New York: Wiley, 1951.
- Obonai, T. Induction effects in estimates of extent. J. exp. Psychol., 1954, 47, 57-60.
- Paterson, D.G., and Tinker, M.A. The part-whole proportion illusion in printing. J. appl. Psychol., 1938, 22, 42; -425.
- Pfaffman, C. The sensory and motivating properties of the sense of taste. Nebraska Symposium on Motivation, Lincoln, Neb.: University of Nebraska Press, 1961.
- Pfaffmann, C. Sensory processes and their relation to behavior: studies on the sense of taste as a model S-R system. Psychology: A study of a science (S. Koch, ed.) Vol. I, New York: McGraw-Hill, 1962, 380-416.
- Revesz, G. Psychology and art of the blind. New York: Longmans, Green, 1950.
- Robinson, J.S., Brown, L.T., and Hayes, W.H. Test of effects of past experience on perception. Percept. mot. Skills 1964, 18, 953-956.
- Rock, I. and Brosgole, L. Grouping based on phenomenal proximity. J. exp. Psychol., 1964, 67, 531-538.
- Rock, I., and Ebenholtz, S. Stroboscopic movement based on change of phenomenal rather than retinal location. Amer. J. Psychol., 1962, 75, 193-207.
- Rock, I., and Leaman, Robin. An experimental analysis of symmetry. Acta Psychologica, 1963, 21, 171-183.
- Roelofs, C.G. Convergence and depth perception. Acta Psychologica, 1960, 17, 193-217.
- Rubin, E. Visuell wahrgenommene Figuren. Copenhagen, 1921.
- Scholtz, W. Experimentelle Untersuchungen über die phänomenale Größe von Raumstrecken, die durch Sukzessiv-Darbietung zweier Reize begrenzt werden. Psych. Forsch. 1924, 5, 219 ff.
- Snygg, D., and Combs, A.W. Individual behavior. New York: Harper and Row, 1949.
- Squires, P.S. Stereopsis produced without horizontally disparate stimulus loci. J. exp. Psychol., 1956, 52, 199-203.

- Steger, J.A. A dimensional study of lightness assimilation and contrast as a function of differential stimuli. Unpublished doctoral dissertation, Kansas State University Library, 1964.
- Suedfeld, P., Grissom, R.J., and Vernon, J. The effects of sensory deprivation and social isolation on the performance of an unstructured cognitive task. Amer. J. Psychol., 1964, 77, 111-115.
- Thorndike, E.L. Animal Intelligence. Psychol. Rev. Monogr. Supp., 1898, 2, Whole No. 8.
- Tinbergen, N. The Study of Instinct. Oxford University Press, 1951.
- Titchener, E.G. A textbook of psychology. New York: MacMillan, 1909.
- Turner, E.D., and Bevan, W. Simultaneous induction of multiple anchor effects in the judgment of form. J. exp. Psychol., 1962, 64, 589-592.
- Walk, R., Gibson, Eleanor J., and Tighe, T. The behavior of light- and dark-reared rats on a visual cliff. Science, 1957, 126, 80-81.
- Walls, G.L. "Land! Land!" Psychol. Bull., 1960, 57, 29-48.
- Wertheimer, M. Experimentelle Studien über das Sehen von Bewegung. Z. f. Psychol., 1912, 61, 161-265.
- Wertheimer, M. Untersuchungen zur Lehre von der Gestalt. II. Psychol. Forsch., 1923, 4, 301-350. (English translation in Readings in perception D.C. Beardslee and M. Wertheimer, eds.). New York: D. Van Nostrand, 1958).

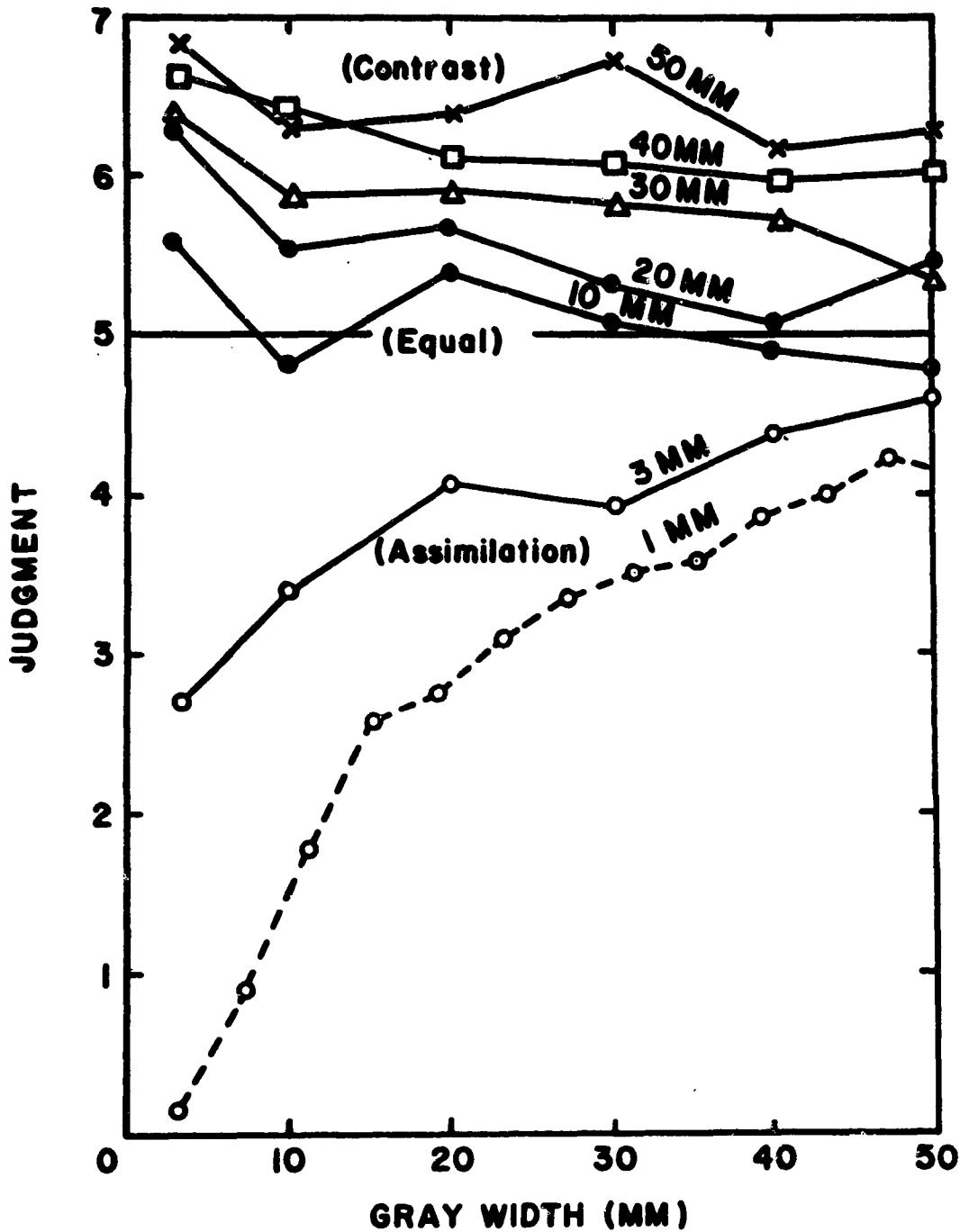
FOOTNOTES

<sup>1</sup>Preparation of this chapter was supported in part by the Office of Naval Research under Contract Nonr-3634 (01) with Kansas State University

<sup>2</sup>I am indebted to Mrs. Ruth Hilton Burgert for this description and the figure which were furnished by her brother who was the synesthetic observer.

#### LEGEND FOR FIGURE 1

Fig. 1. Contrast and assimilation as a function of gray width for each width of line. The broken curve for 1-mm. line width is from a study by Helson and Rohles (1959). The parameter of the curves is line width. (From Helson and Joy, 1962. With the permission of Psychologische Beiträge.)



Helson: FIG. 1.

400

#### LEGEND FOR FIGURE 2

Fig. 2. Assimilation as a function of white line separations. The light gray background has 80 percent reflectance. Only assimilation is found with all line widths when the reflectances of lines and background are nearly the same. (From Helson, 1963).

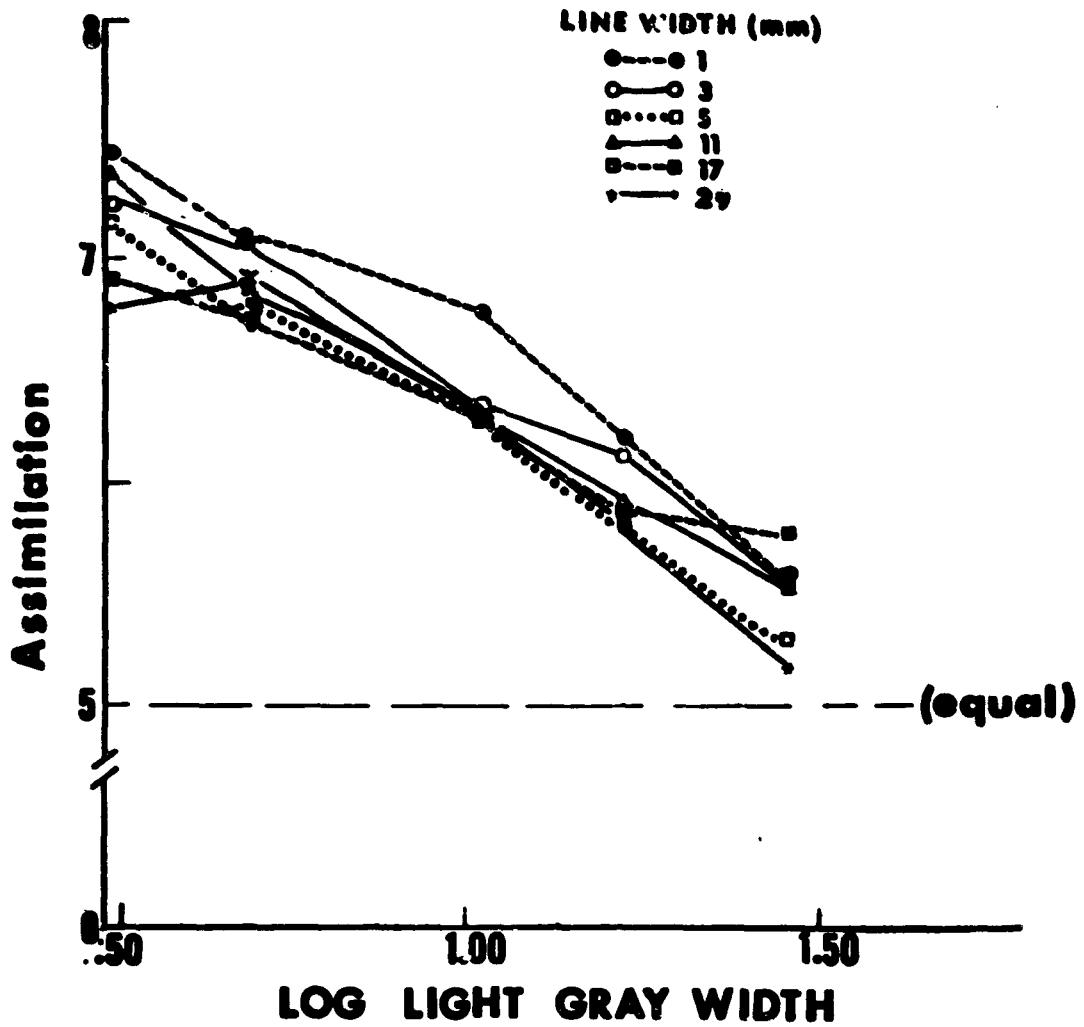


FIG. 2. KELSON

#### LEGEND FOR FIGURE 3

Fig. e. Assimilation as a function of black line separations with background of 14 percent reflectance. Only assimilation is found with all line widths when the reflectances of lines and background are nearly the same. (From Nelson, 1963).

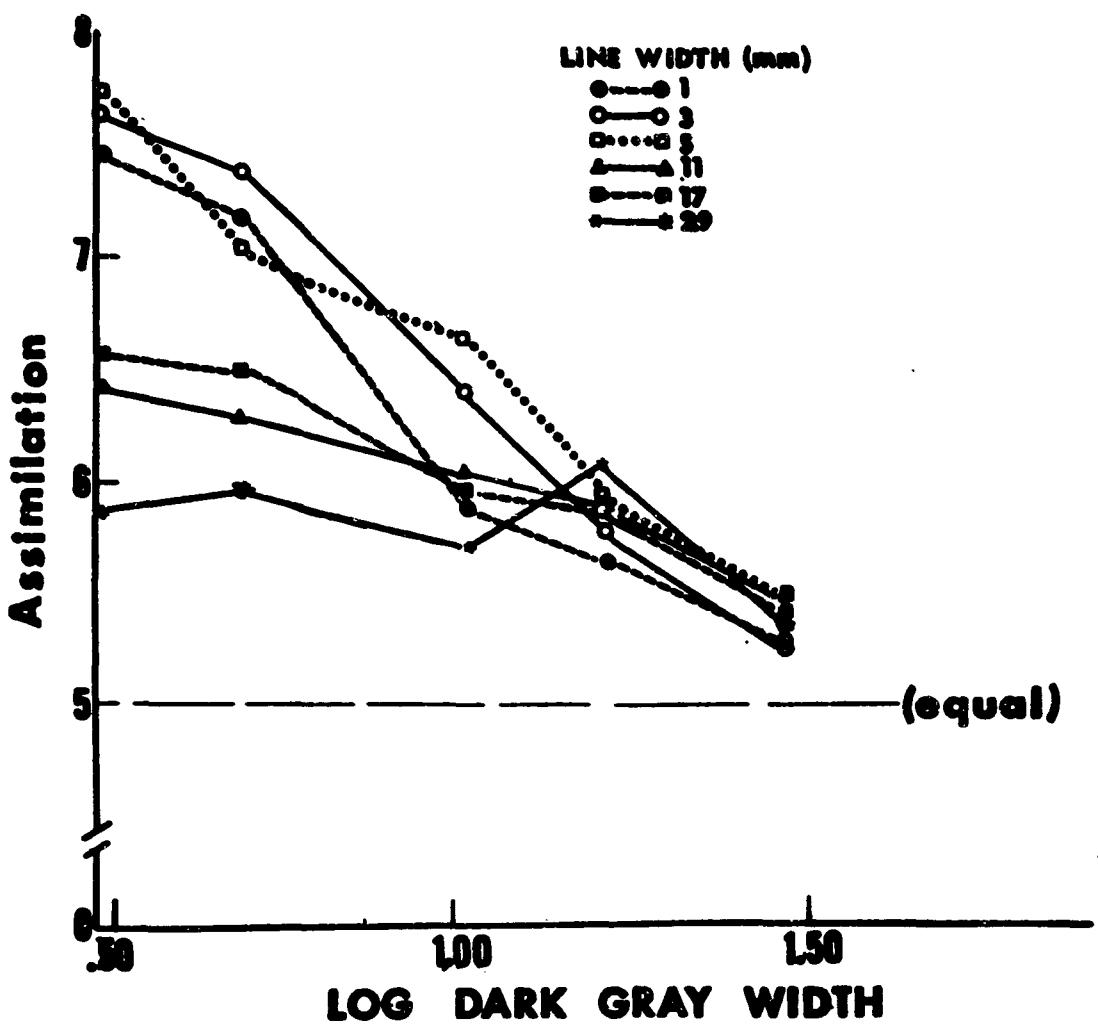


FIG. 3. NELSON

#### LEGEND FOR FIGURE 4

Fig. 4. Domains of assimilation and contrast. Each point in the graph represents the combination of line widths and separations that yield contrast or assimilation. The triangles represent conditions that yield neither contrast nor assimilation. (From Helson and Joy, 1962, with the permission of Psychologische Beiträge).

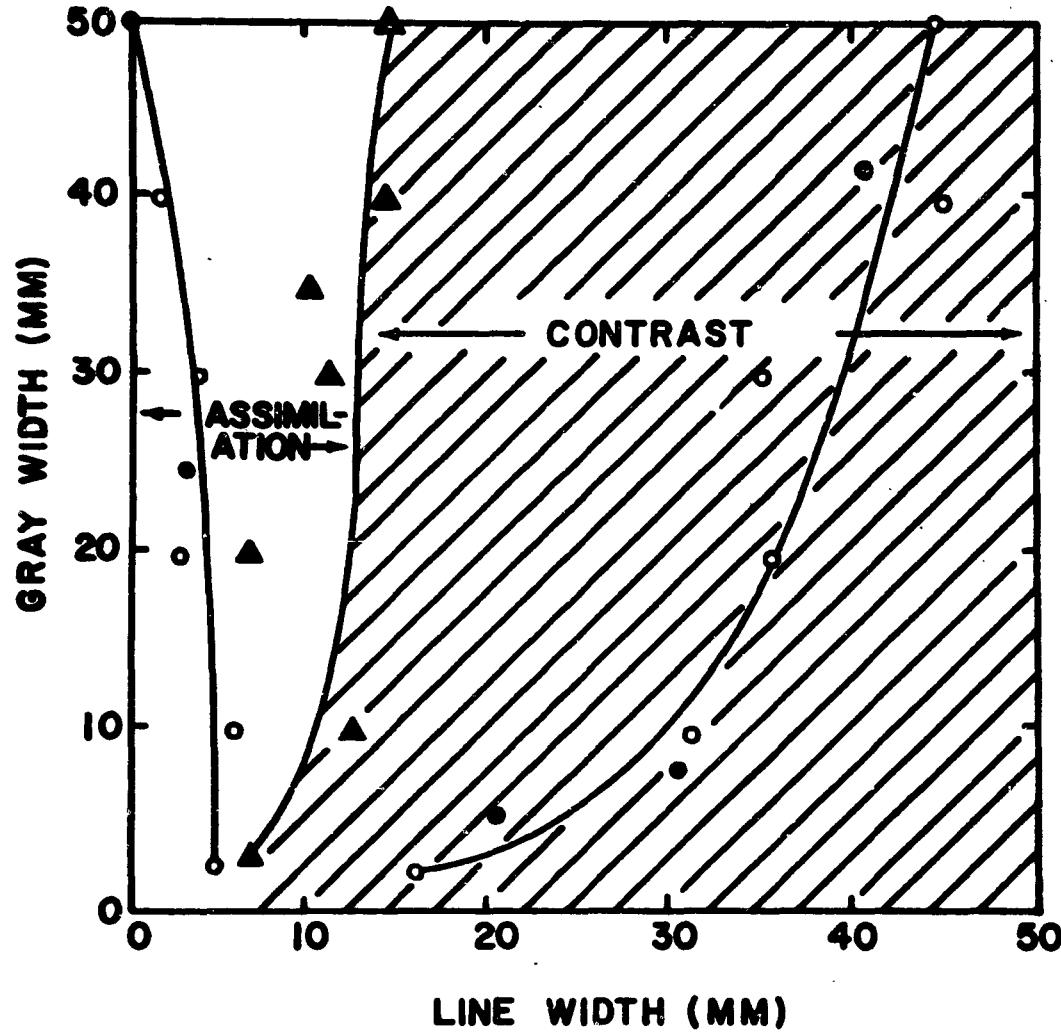


FIG. 4. HELSON

**LEGEND FOR FIGURE 5**

**Fig. 5. Pattern of colors aroused on hearing orchestral  
music as reproduced by a synesthetic subject.**

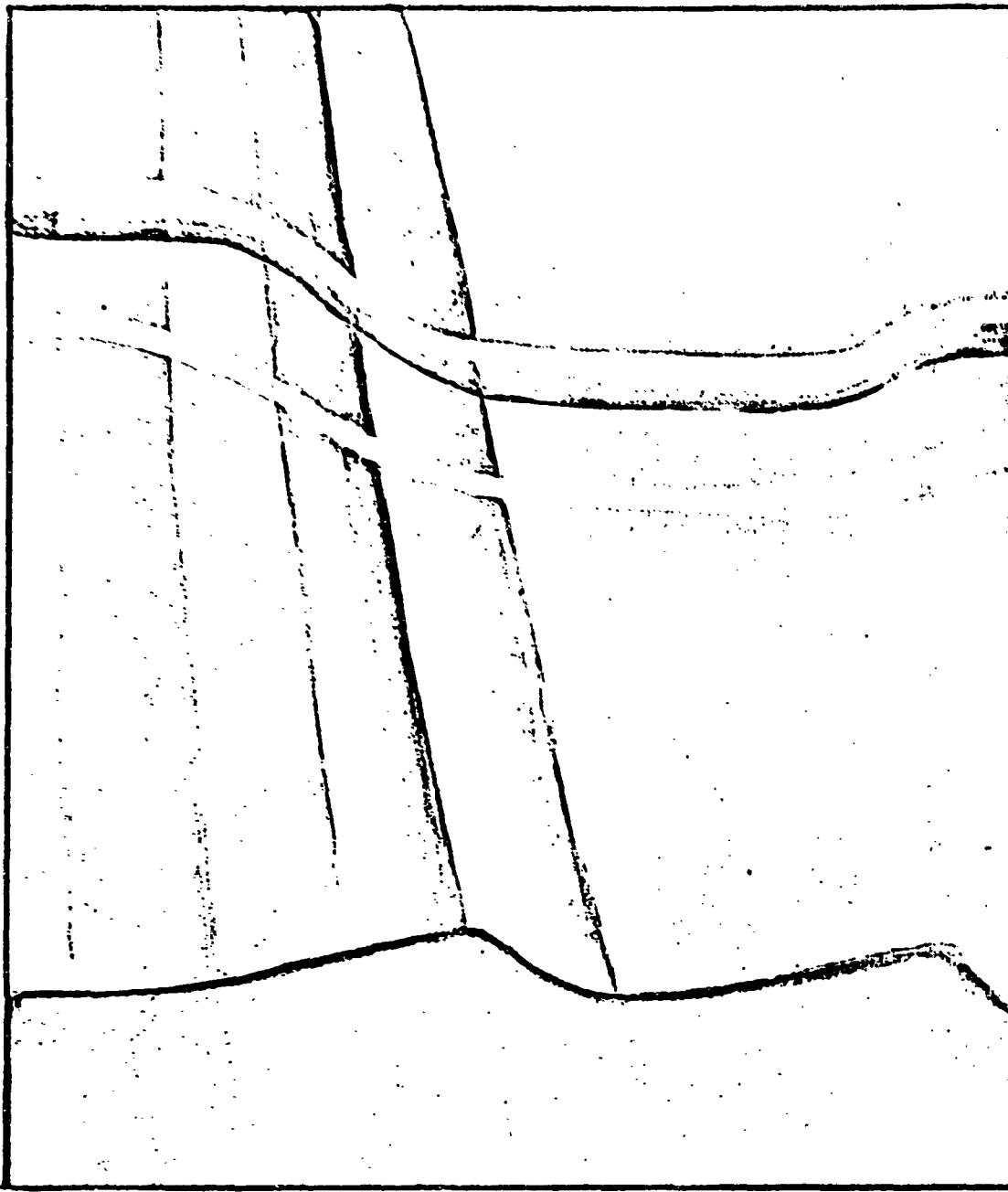


FIG. 5. HELSON

original of above is in color.

LEGEND FOR FIGURE 6

Fig. 6. Direct estimates of number as a function of jar-size and the way in which the jars are perceived. L and S indicate large and small jars, F and G indicate figure and ground instructions. The dotted line represents perfect estimates. (From Bevan, Maier, and Helson, 1963. With the permission of the Amer. J. of Psychol.)

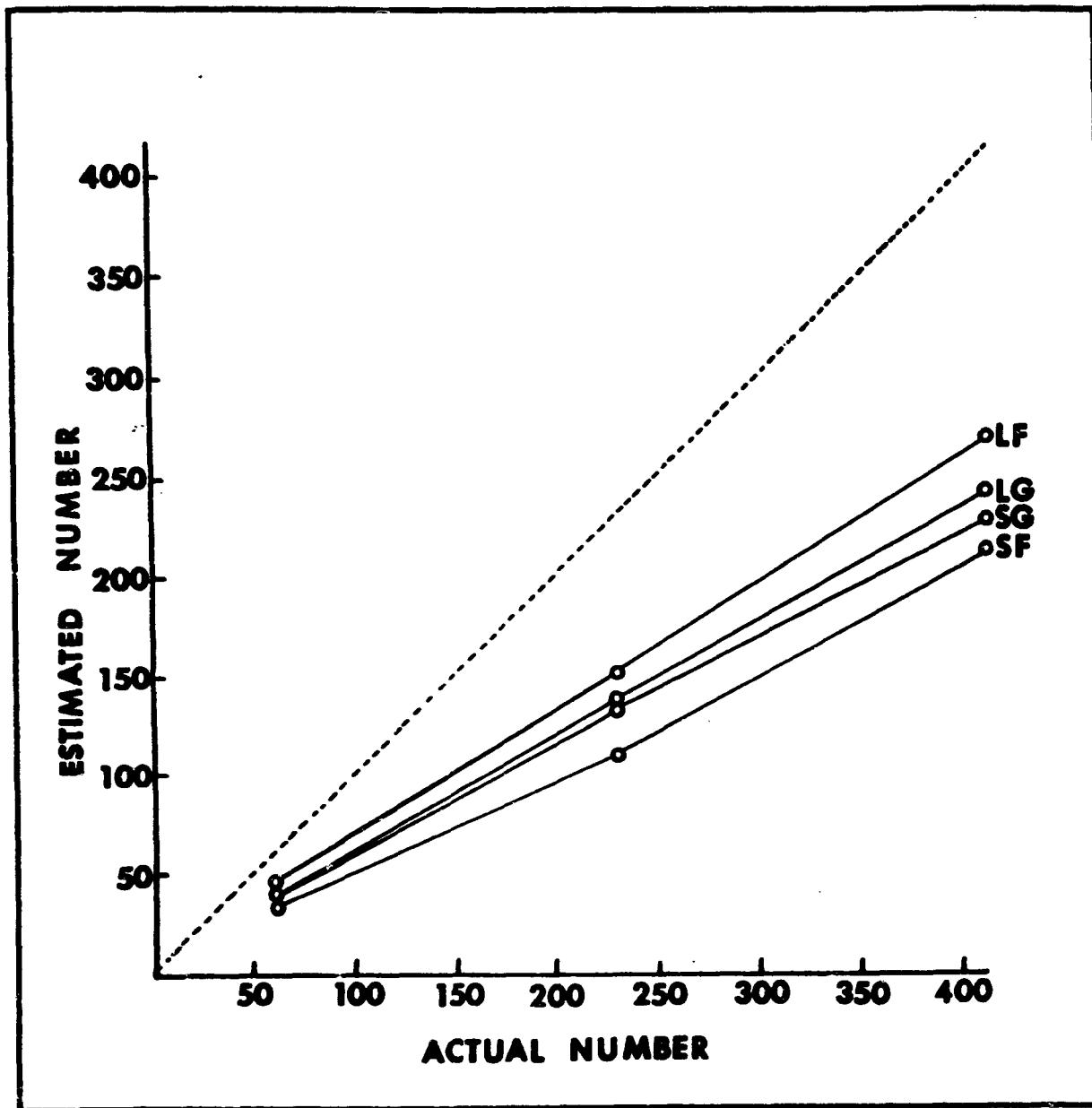
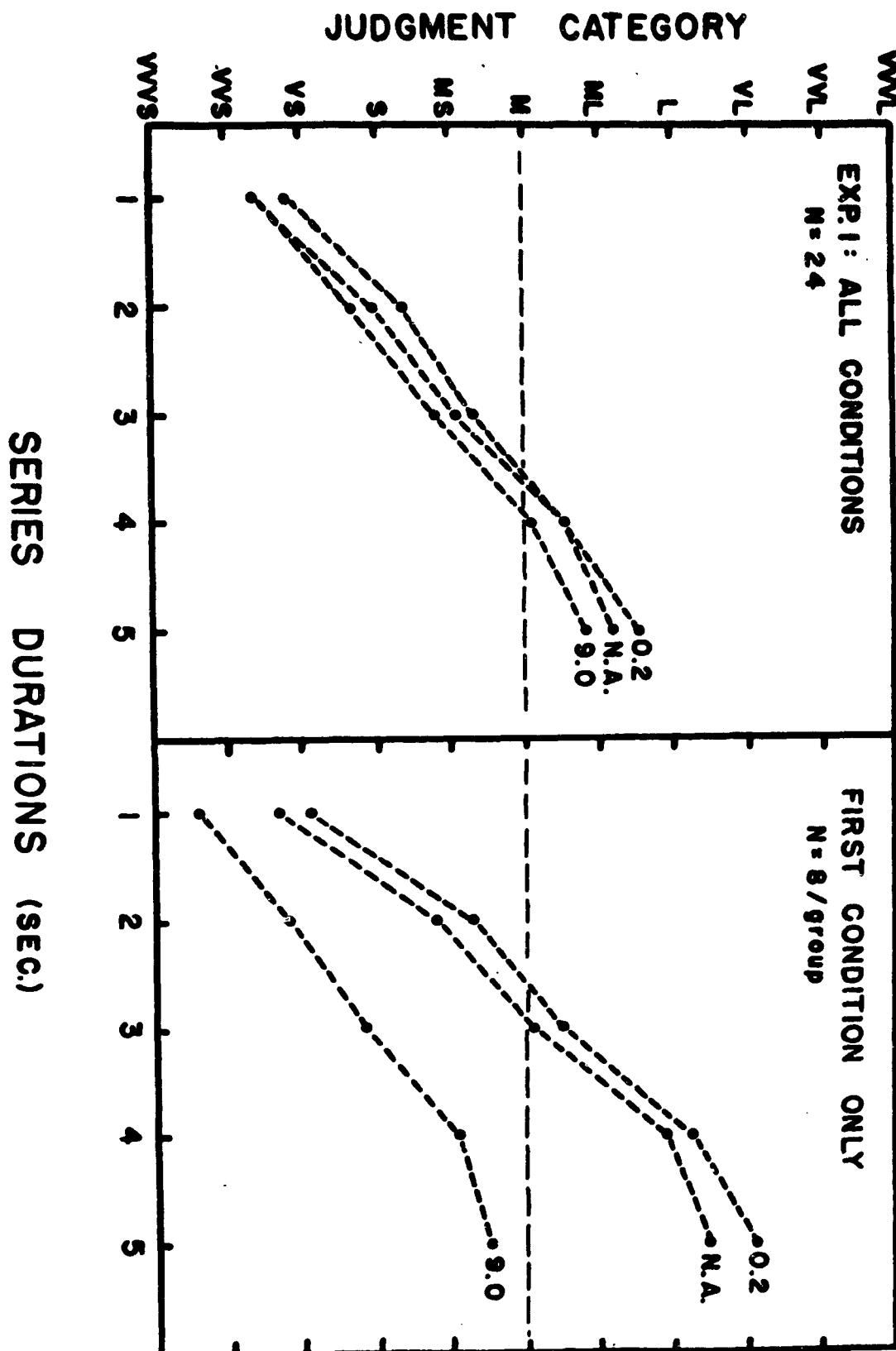


FIG. 6. HEISON.

#### LEGEND FOR FIGURE 7

Fig. 7. Intramodal anchor-effects in judgments of visual durations with anchors above and below the series intervals. The left panel confounds order effects; the right panel shows results for each condition presented first. (From Behar and Bevan, 1961. With the permission of the American Journal of Psychology).

FIG. 7. HEDSON



#### LEGEND FOR FIGURE 8

Fig. 8. Judged sizes of stimuli in the first (impression) phase showing expected anchor effects with small (0.30 in.) intermediate (1.96 in.), and large (9.0 in.) anchors and under control condition in which only series stimuli were judged. (From Helson, 1964a. With the permission of American Psychol. Association.)

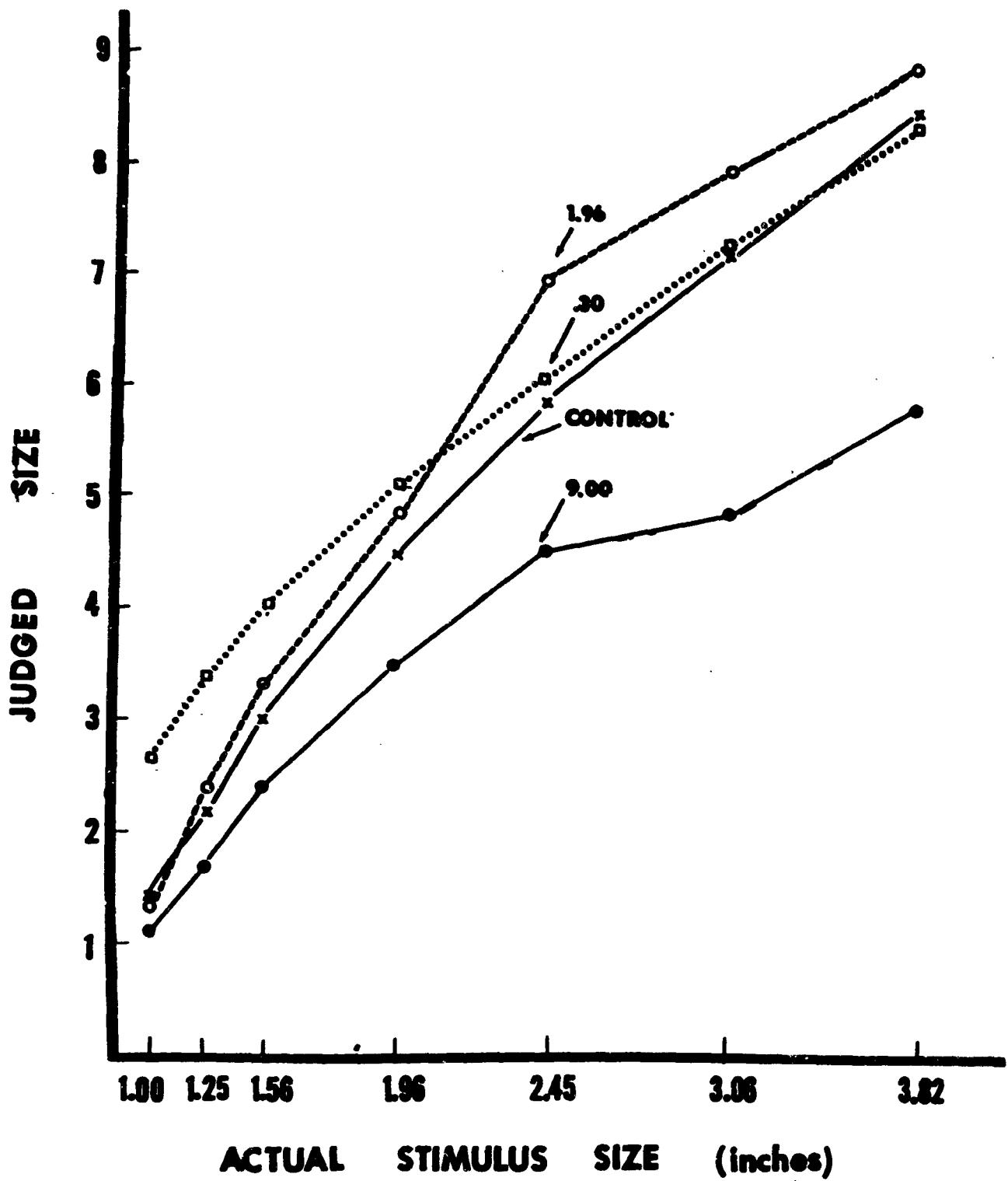


FIG. 8. HELSON

LEGEND FOR FIGURE 9

Fig. 9. Smallest, middle, and largest of the series stimuli recalled 1 week after initial presentation. (From Nelson, 1964 a. With permission of American Psychological Association.)

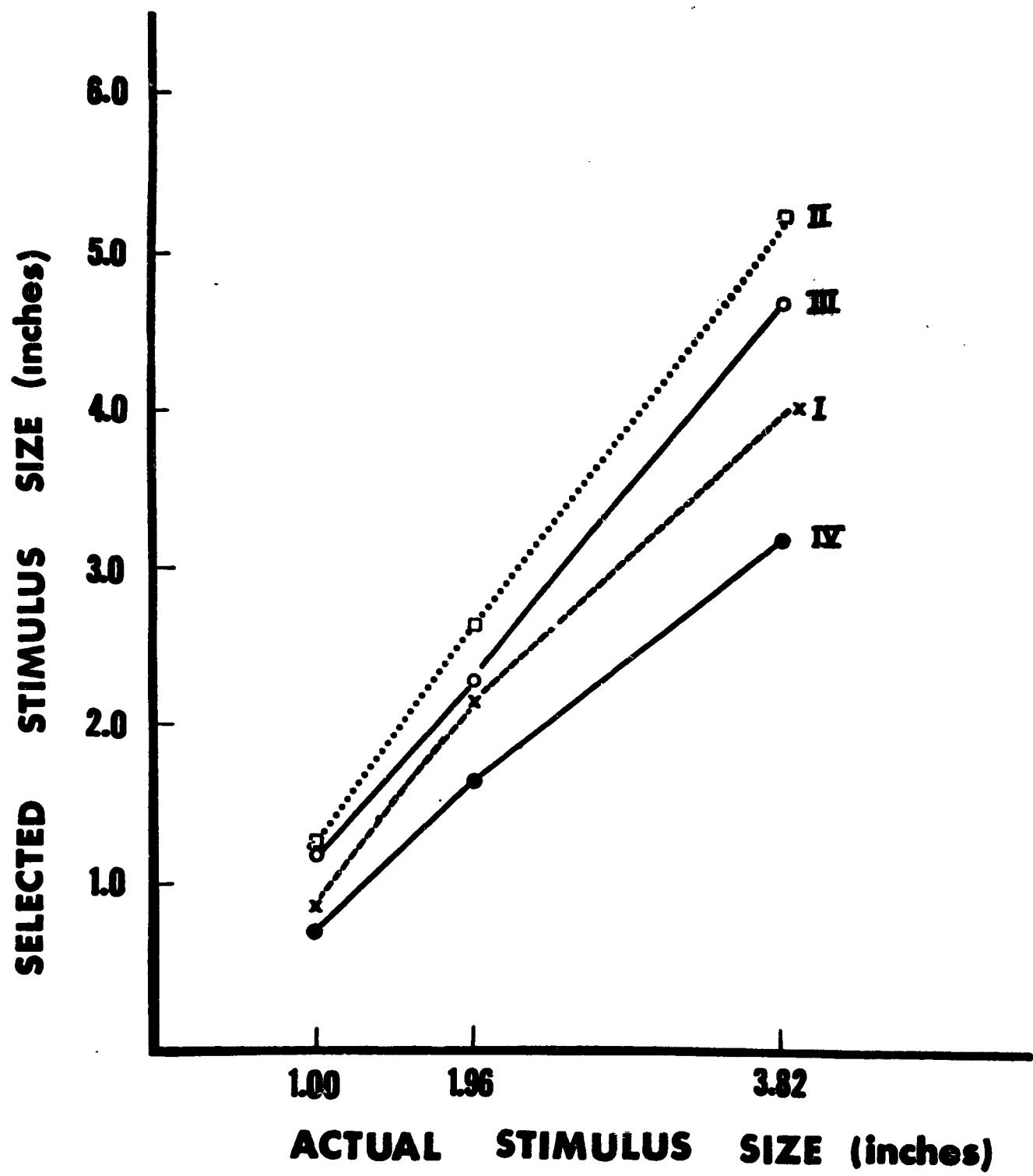


FIG. 9. NELSON

#### LEGEND FOR FIGURE 10

Fig. 10. Smallest, middle, and largest of the series stimuli recalled 1 week after initial presentation with large (small) anchor if small (large) anchor was employed during the impression phase. (From Helson, 1964 a. With permission of American Psychological Association.)

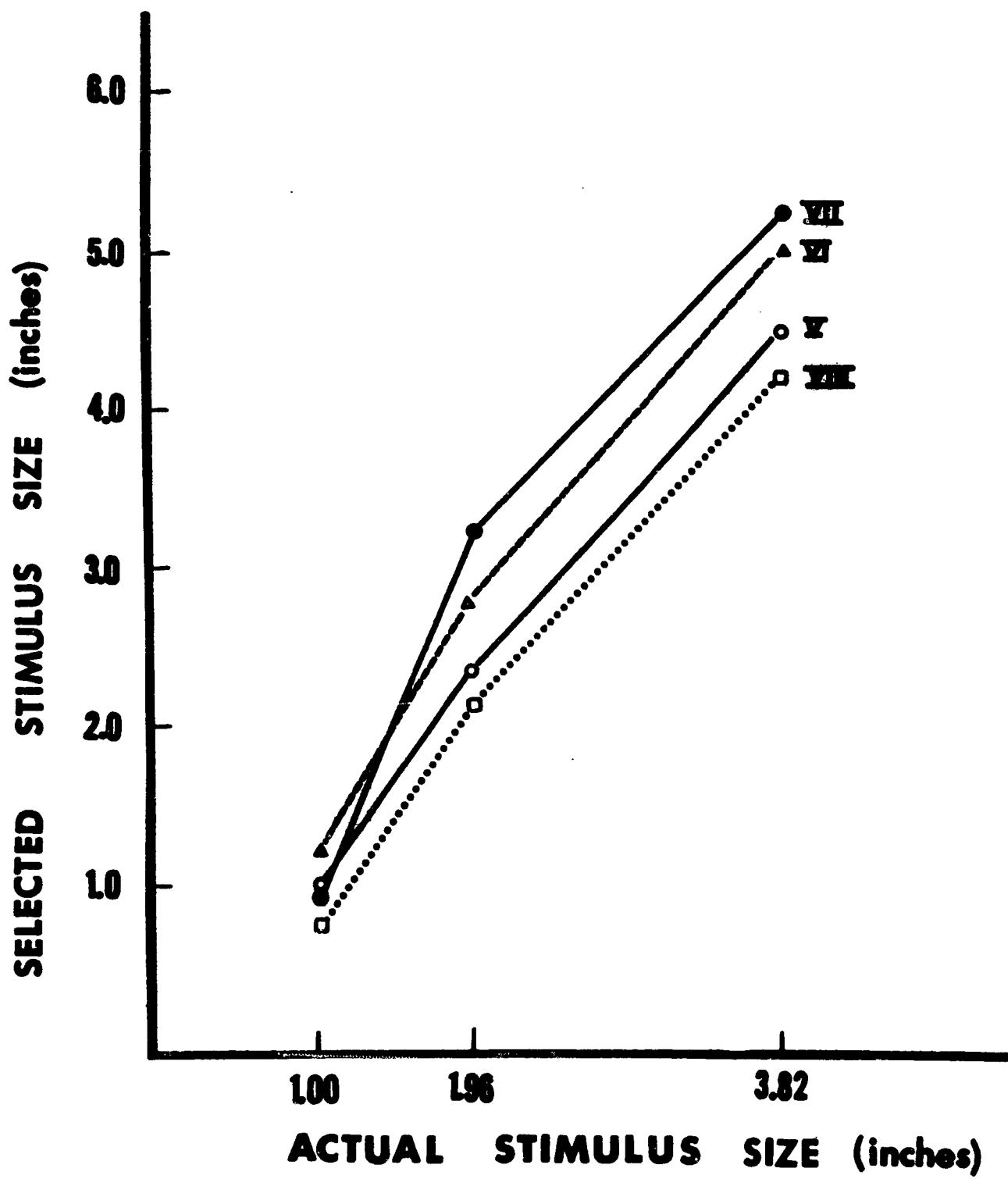


FIG. 10. NELSON

LEGEND FOR FIGURE 11

Fig. 11. Locus of ALs as a function of extremely light to extremely heavy anchors. Below 25 grm. anchors have less and less effect as the ALs approach the AL of the series or no anchor condition. (From an unpublished study by Helson and Masters.)

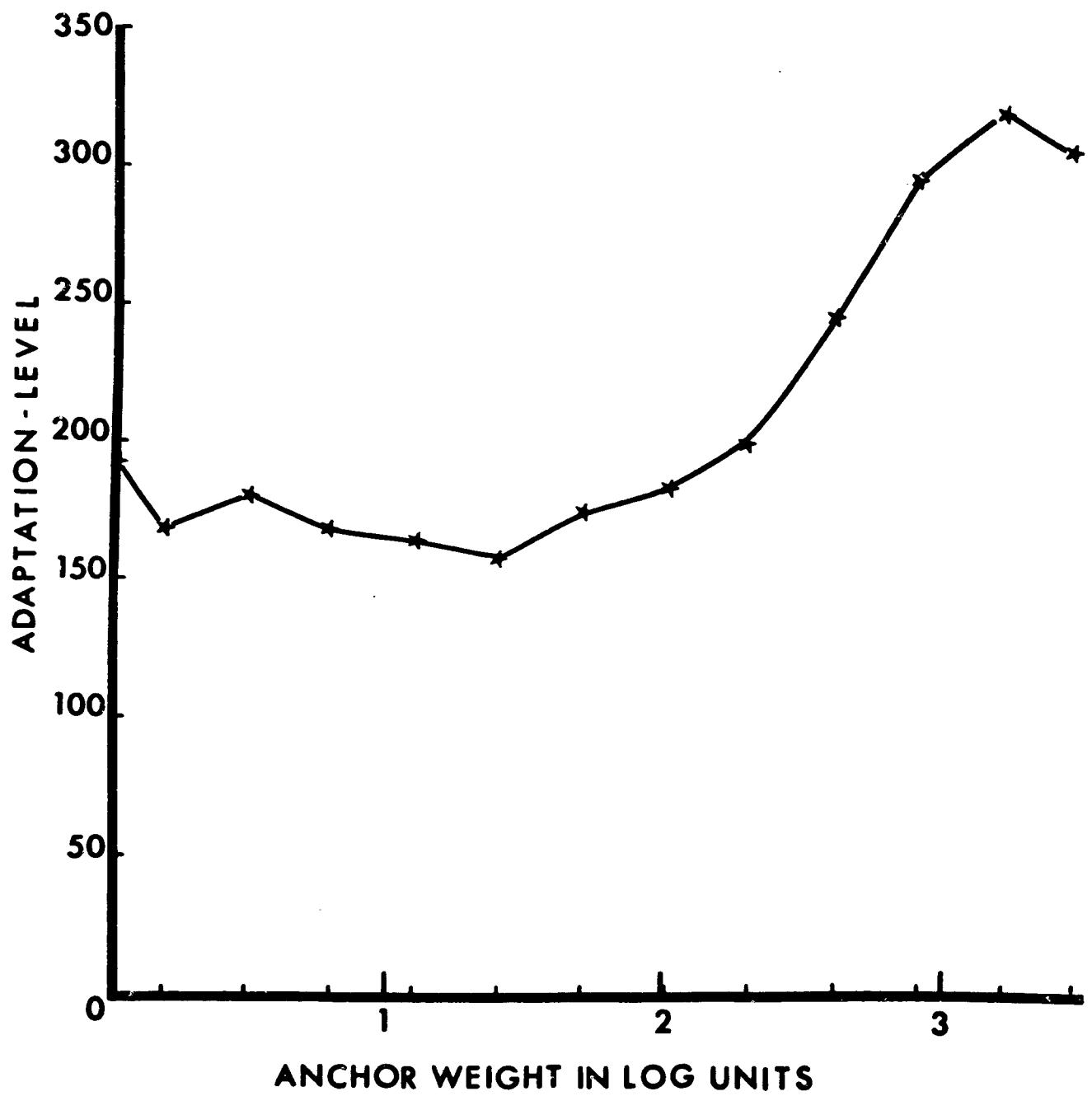


FIG. 11. HESON. PERCEPTION

#### LEGEND FOR FIGURE 12

Fig. 12. Error of overestimation with judged area held constant while size of background area is varied. (Background area was increased from Stimulus 1 to Stimulus 7.) The parameters of the curves indicate relative size of the areas judged. (From Helson and Bevan, 1964. With the permission of American Psychological Association.)

PERCENT OVERESTIMATION

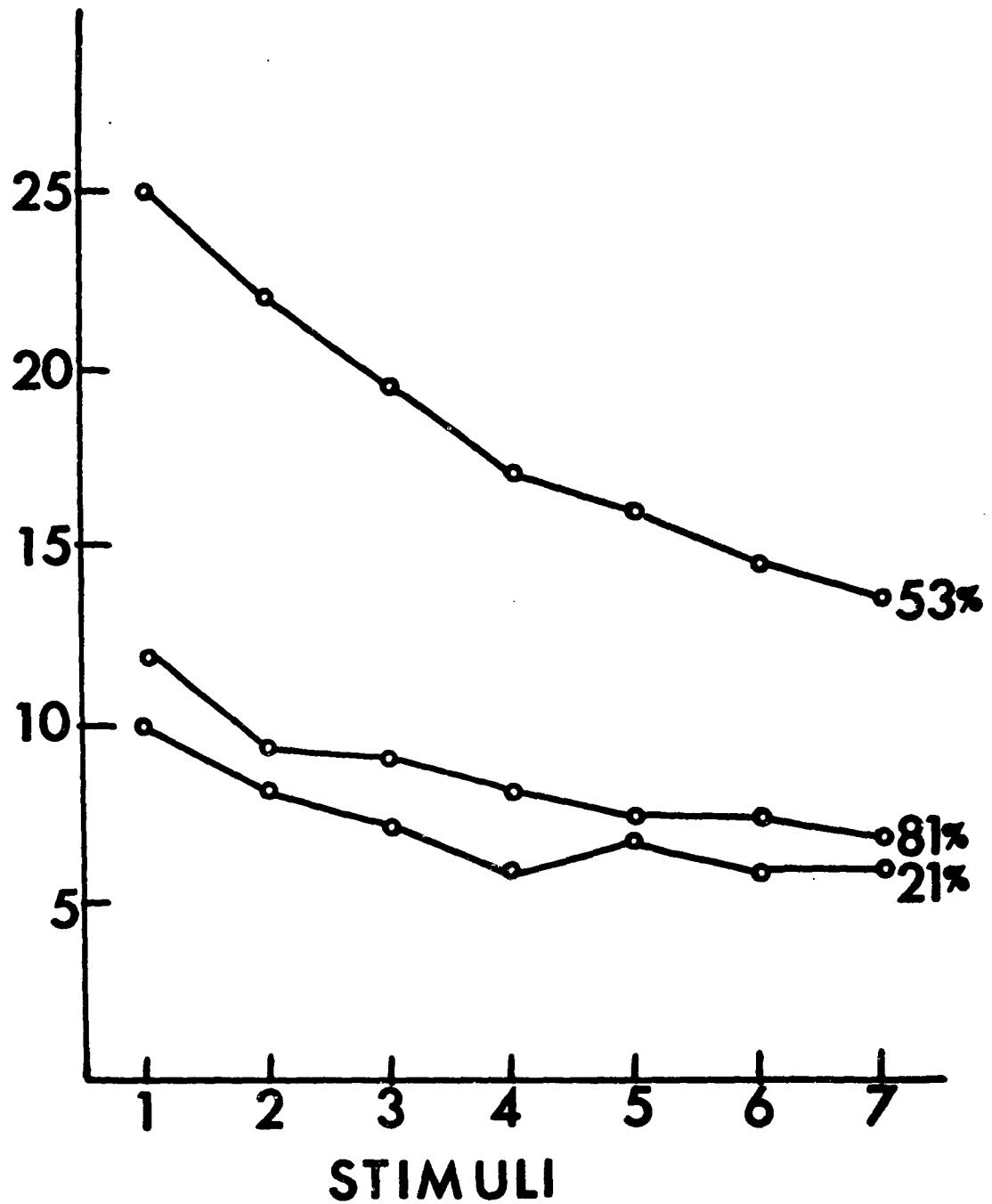


FIG.12. HELSON